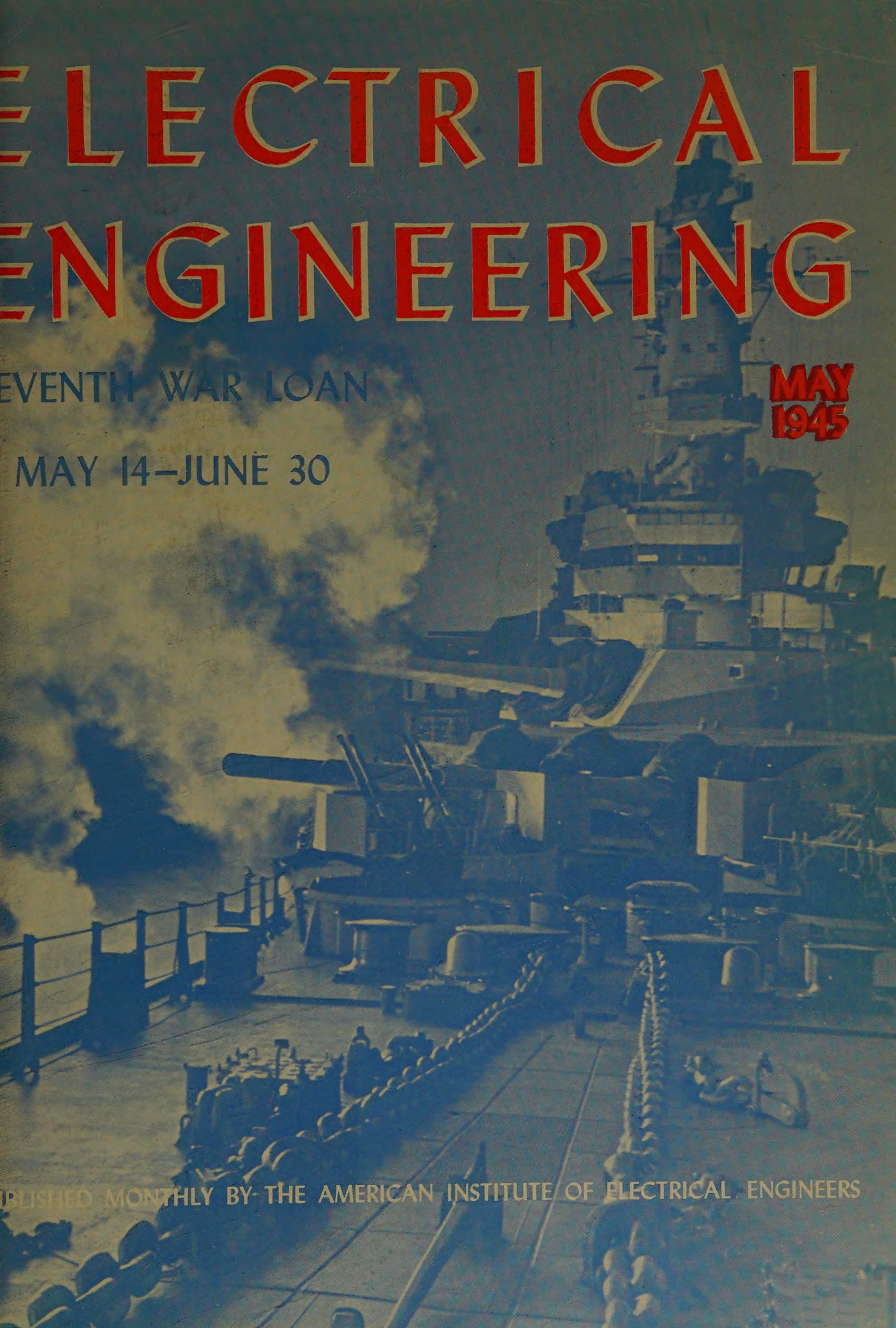
ELECTRICAL ENGINEERING



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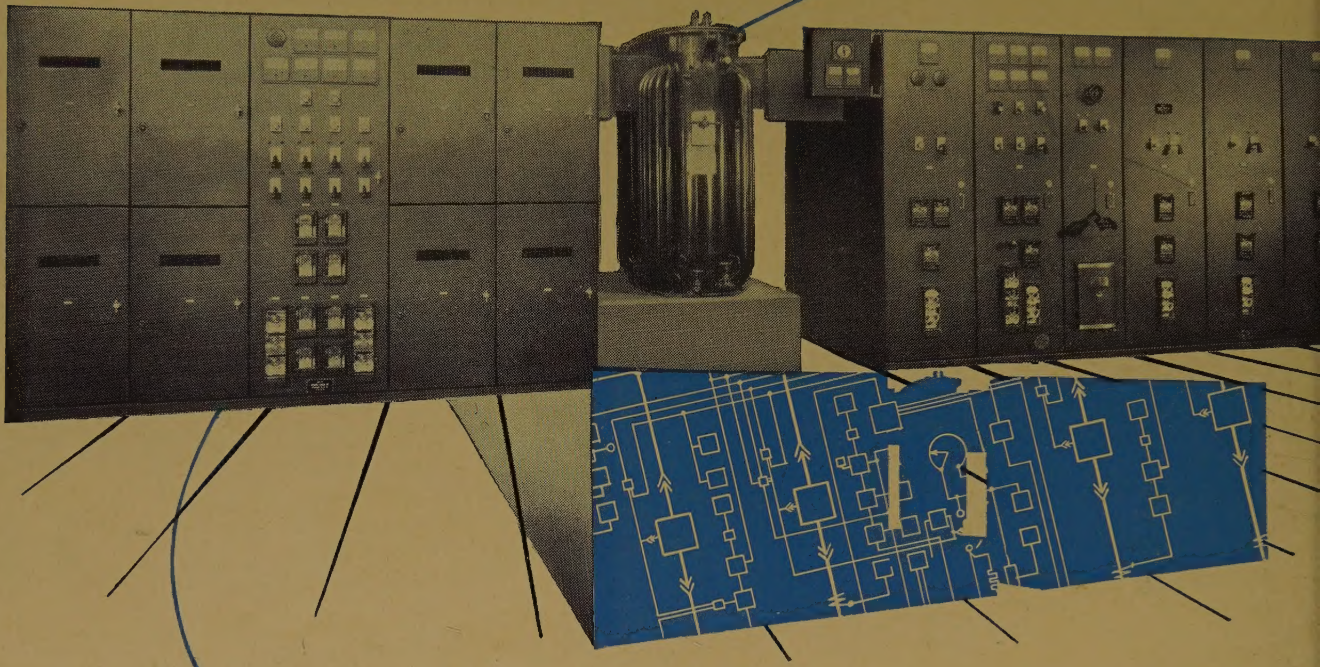

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The Cover: Main battery salvo of USS *Missouri,* 45,000-ton superdreadnaught, showing the three 16-inch guns of number-2 turret as seen from the bow. This is the fourth of the mighty *Iowa* class ships to be commissioned.
Official United States Navy photo

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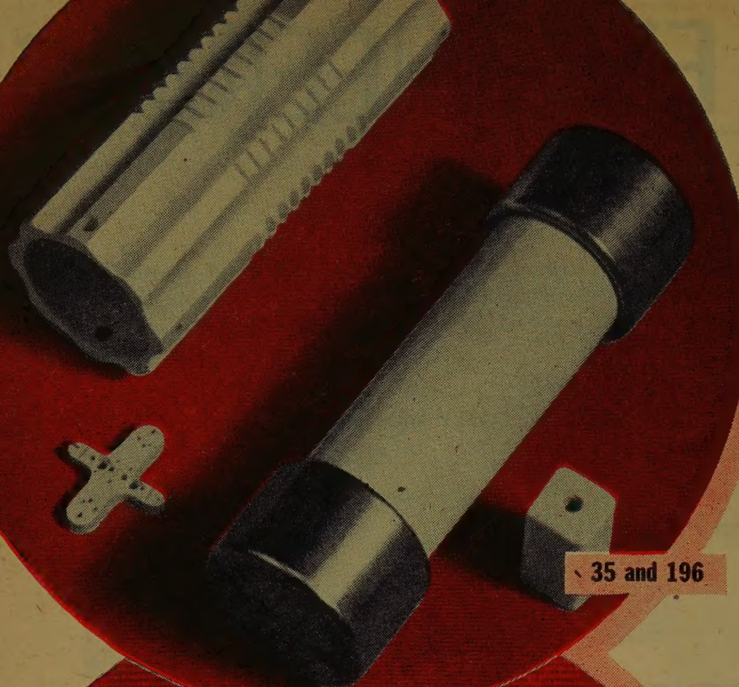
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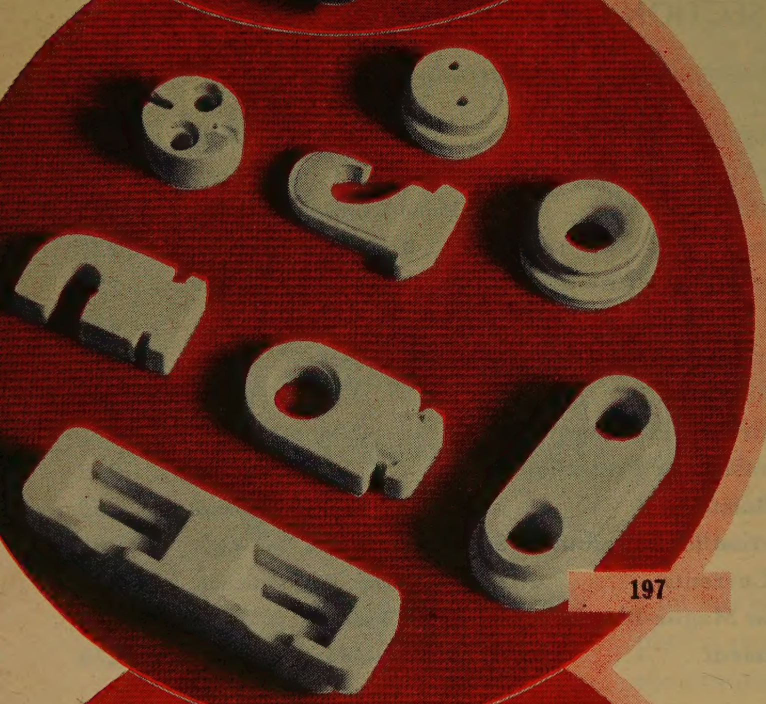
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ELECTRICAL ENGINEERING
VOLUME 64, NUMBER 5 MAY 1945

Army Ground Communication Equipment

ROGER B. COLTON

The requirements for combat communication equipment, some of the problems in its development and production, and the testing and observation of it in actual operation in the field are recounted in this article. Wire, switchboards, radio equipment, types of control, and carrier systems are discussed.

THE ARMY, in communication work, uses two fairly distinct types of equipment—fixed-type communication equipment and combat-type communication equipment. The so-called fixed type of equipment corresponds, or at least initially corresponded, very closely to normal commercial communication equipment with which we are all familiar and have been familiar for many years. Combat-type communication equipment, on the other hand, is in many respects entirely different from ordinary commercial communication equipment, although there has been a tendency throughout the course of the war to introduce some of the features of normal commercial equipment into the combat equipment and likewise to replace the fixed communication equipment, ordinarily used by the Army in the rear areas, to a considerable extent by combat types of equipment.

When war became imminent in 1938 or '39, Congress made some considerable preparations in the way of providing for development and even for production of those items of military equipment which are associated in most people's minds with military operations: namely, such things as airplanes, naval vessels, artillery cannon, small arms, and explosives. There was not, however, a general recognition of the fact that combat communication equipment is a highly specialized weapon and that development in advance and procurement in advance of such equipment was necessary if the Nation was to be prepared for war. This lack of appreciation of the importance of specialized military communication cannot be charged to any one person or persons either in the Army or out. It may, however, be stated as a fact.

The initiation of extensive Army maneuvers in 1939 and 1940 brought to the attention of all concerned the necessity of providing special combat communication equipment as well as many other special items of military equipment not in the so-called armament classification. Consequently, in June of 1940, considerable funds were appropriated for the development of combat communication equipment. Those of us in the Signal Corps and the communications personnel in the various using arms, such as the Infantry, Cavalry, Field Artillery and Antiaircraft Artillery, of course were convinced of the necessity for the best possible combat communication equipment and had not been idle during the preceding years. In anticipation of that day when the necessary funds might be provided and also with a view to creating sufficient interest to insure that adequate funds would be provided eventually, beginning in 1938 we had drawn up at the Signal Corps Laboratories, Fort Monmouth, N. J., a series of five-year plans for the development of a complete line of equipment and had circulated these plans where they would do the most good as an effective planning tool. The funds estimated in these plans were very modest indeed but were, generally speaking, initially considered by those who read them to be fantastic.

In connection with this program a demonstration of all available types of signal communication equipment was arranged at Fort Knox, Ky., November of 1939. During and immediately following this demonstration, Lieutenant Colonel Louis B. Bender, Major Hugh Mitchell, and Captain David E. Washburn, from the research and development division of the Office of the Chief Signal Officer and the personnel of the Signal Corps Laboratories at Fort Monmouth contacted those agencies of the using arms that had cognizance of communication development. As a result of this action, by January 1940 we had a fairly definite and also a very moderate program for the development of equipment largely agreed upon, and as a result of the imminence of war Congress appropriated considerable funds in June of 1940.

These funds became available to the Signal Corps Laboratories in August, and we then were faced with the necessity for developing and putting into production at the earliest possible moment the new items of communication equipment. As of that date the entire personnel of the Signal Corps Laboratories at Fort Monmouth, N. J., consisted of eight officers and 148 civilian employees. The following personnel was charged with the responsibility of development of ground signal equipment as indicated:

Colonel R. B. Colton, director of laboratories
Captain J. D. O'Connell, executive officer
Lieutenant A. F. Cassevant, on detail from Coast Artillery Corps

Project Officers:
Captain Reginald Lyman
Captain J. D. O'Connell
Captain R. V. D. Corput, Jr.
Captain Oscar C. Maier

Section Chiefs:
G. A. Graham, wire communication
W. S. Marks, vehicular radio
J. Hessel, field radio
O. White, automotive and power
R. H. Noyes, product engineering

Liaison Officers:
Captain Stewart Beckley, Field Artillery
Captain Dana McBride, Cavalry
Major Ernest J. Barker, Infantry

Though not actually on duty with the Signal Corps Laboratories, Major Grant A. Williams, then signal officer of First Mechanized Cavalry and now signal officer of First Army, pioneered Armored Force communications and worked closely with the laboratories.

The proportion of the total possible personnel available for work on the communication program at that time amounted to approximately one fifth, or two officers and 30 civilians. It was necessary therefore rapidly to expand our personnel and at the same time to inaugurate a large development program.

In the years preceding the imminence of war, the Army (neglecting overseas garrisons) consisted of some half-dozen Regular Army divisions, few, if any, of which were completely up to strength, and perhaps a half-dozen National Guard divi-

Essential substance of an address presented at a section meeting of Institute of Radio Engineers, September 28, 1944, in Dayton, Ohio.

Major General Roger B. Colton former chief of the engineering and technical service of the Signal Corps, United States Army, Washington, D. C., is air communications officer, Headquarters, Air Technical Service Command, Wright Field, Dayton, Ohio.

sions. There was a considerable number of service and technical troops, but these were scattered throughout the country at some 200 military posts, camps, and stations, and were in effect principally local housekeeping detachments. Corps and army organizations did exist, but they existed almost entirely on paper. As a consequence, as might be expected, specialized combat equipment had been provided essentially only for divisional troops, and even in the case of divisional troops the equipment provided was inadequate in quantity and though good was of rather old design. There was in existence one battalion called the 51st Signal Battalion, which at that time provided the only field unit that could be used for line-of-communication signal work.

TELEPHONE EQUIPMENT

First, as regards telephone equipment, we had the *EE*-8 field telephone which had been designed at the Signal Corps Laboratories in co-operation with commercial telephone-manufacturing companies. The development of this telephone was essentially completed in 1938, and it was therefore quite modern and up-to-date and has stood the test of the war without any major modification. It is still the best field telephone in the world.

The wire being used at this time was known as 110-*B*. This wire had been developed in the period between the wars by the Signal Corps Laboratories in co-operation with the wire manufacturers, and it too has stood the test of war. I cannot say that it is still the best field wire in the world, because many shortages during the early part of the war forced the Signal Corps to make substitutions which have degraded the wire to some extent. The lack of stranding machines in this country forced us initially to accept wire with parallel lay, and as a result some of our original wire occasionally failed, owing to the individual strands kinking and therefore being very near to the surface of the insulation. The shortage of rubber also forced us to accept the minimum possible amount of rubber in the insulation of the wire, and the change from natural rubber to artificial rubber in the past year has done the wire no good. Nevertheless, this wire has proved to be sufficiently good for military use.

Radio engineers may think that wire is a simple and prosaic object. However, when one considers that at the present time we are producing approximately 1,000,000 miles of 110-*B* field wire per month and still are barely able to satisfy demands from the fighting fronts, one realizes that it is of the utmost importance to the Signal Corps.

In August 1940 for switchboards we had the *BD*-71 and *BD*-72 which are 6- and 12-drop monocord switchboards used principally in the regiments. These boards are in effect the World War French monocord switchboard *BD*-9 and *BD*-11, but in a different housing and having an operator's head and chest set added. They are simple sturdy boards and have given satisfactory service throughout the war. They are, however, heavier than need be by perhaps as much as 50 per cent. These boards could and should have been redesigned early in the war, except for the fact that there were so many other problems of greater urgency to be handled.

The division switchboard of this era was the *BD*-14, a very good World War switchboard, but somewhat antique in design and unnecessarily heavy for the service it renders. It was not considered satisfactory to the using arm (in this case, the Signal Corps) and was one of the pieces of equipment that needed to be redesigned immediately.

For a corps switchboard at this time we had in process of development but not yet developed completely the *BD*-89 developed by the Signal Corps Laboratories, and in the same category for the Army we had the *TC*-1 also developed by the Signal Corps Laboratories based on a Western Electric rural telephone design. In the case of these boards, our problem was largely one of getting them ready for production, and the boards have given good service throughout the war.

For laying and recovering field wire, there was at this time, already recently developed and in production, the reel unit *RL*-26, and this reel unit has given satisfactory service without major change.

At this point it will be appropriate to discuss the difference between commercial and combat wire equipment. First, as regards the field telephone, substantially all commercial telephones are of the common-battery type and are designed for either wall mounting or desk operation. Common-battery operation is not feasible in the field on account of the reduced distance over which such lines can be operated as compared with local-battery lines. Furthermore, in the field, telephones frequently must be used on a point-to-point basis rather than on a central-switchboard basis. However, in many cases even smaller units are located temporarily in situations in which service is obtainable from common-battery exchanges. Therefore, it is at least advisable, if not necessary, that the field telephone be capable of being operated on either common battery or local battery. If we add to these requirements the requirement that the telephone shall be of such shape and weight as to be carried conveniently by the soldier and so rugged that when thrown into a truck it will operate again, it is evident that, while no new principles are involved in the design of the field telephone, new and novel engineering techniques were evolved which resulted in lighter weight and improved performance. The individuals who ate and slept with these wire problems were Major Washburn, Captain Lyman, Mr. Graham, Mr. Wyly, Mr. Tapper, Mr. Parmer, Jefferson Davis, and Byron Anderson.

The requirements for field wire are that one should be able to talk a long distance over the wire, and yet it must be sufficiently strong to permit its being laid from a truck with the consequent inevitable stresses that occur in this manner of laying. It is also subject to being run over by trucks, tanks, and other vehicles. Furthermore, since it is required in large quantities, it must be as cheap as it is possible to make it. As a result, field wire is made of four strands of

Signal Corps photo

Figure 1. Corporal William H. Godfrey, Technical Sergeant Clifford J. McCarthy, and Sergeant Trozy R. Barker operate liaison sets on an airfield somewhere in England

steel wire, 0.013 inch in diameter, two strands of copper wire 0.013 inch in diameter, and one strand of copper wire 0.014 inch in diameter, with a rubber insulation 0.026 inch in wall thickness and a cotton braid on the outside. Two such wires twisted three turns per foot form *W*-110-*B* field wire.

For the smaller types of switchboards the required military characteristics are light weight, simplicity of operation, high traffic-handling capacity, and sturdiness of design. The omission of the storage battery ordinarily used in common-battery systems makes for lightness of weight. Simplicity of operation is obtained in the *BD*-71 and *BD*-72 by attaching to each jack or line unit its own cord and plug. The use of a separate cord and plug for each jack or line unit also meets the other needed military characteristics of high emergency traffic load by providing 100 per cent cord circuits. As regards the switchboards to be used by divisions and higher units, the requirements are again relative lightness of weight, high traffic handling, and sturdiness of design. However, in the division switchboard we provide four trunk circuits for connection to common-battery exchanges, and 40 magneto lines, while in the corps switchboard we provide 37 common-battery lines and 20 magneto lines and in the Army switchboard 60 common-battery lines and 30 magneto lines. For rear-area use we use standard commercial common-battery telephones, and, while we provide on division, corps, and army switchboards provisions for interconnection with automatic exchanges, our combat equipment has no automatic exchange features other than necessary dials and relays to permit this interconnection.

One of the major contributions in the field of telegraph- and Teletype-switchboard design was the development of the switchboard *BD*-100 designed by Mr. Parmer of the Signal Corps Laboratories. This is one of the lightest-weight and most trouble-free switchboards used in the theaters. It is a ten-line Teletype switchboard, neutral operation, with facilities for connecting three boards in multiple. It is used in connection with standard teletypewriter sets *EE*-97-*A* and has a maximum flexibility for field Teletype operation.

Much emphasis was placed on the fact that the primary means of communication was wire. This is still true—the primary means of signal communication is still wire, but, with the substitution of motor-drawn vehicles for the horse, and with the advent of the tank, there occurs a decisive point early in the campaign—a time in which it is no longer possible to keep up with the advancing forces by means of 35-foot poles and ten-pin crossarms in combination with 110-*B* field wire, which were the prewar means of wire communication.

Consequently, early in the war we began the development of a link to go in between the fixed-pole line construction, which is most suitable for rear areas, and the relatively light field-wire construction, which is most suitable for the advance element. These two systems were the radio-relay carrier system and the spiral-four carrier system. We had the experience of the English to go on in the matter of the spiral-four carrier systems, and it was not too much trouble to convince our operating personnel of its utility.

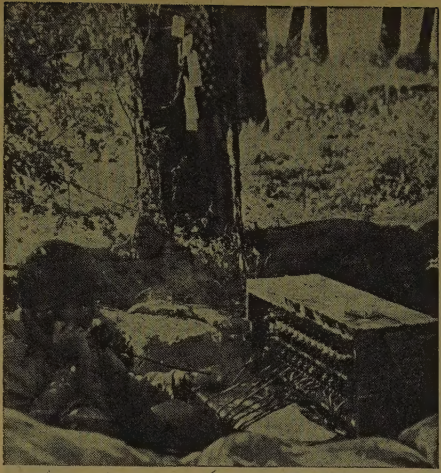

Signal Corps photo

Figure 2. This soldier with his switchboard is in a "king-size" foxhole putting through a telephone call under combat conditions. This is not a combat zone, however, but the area around Goldsboro, N. C., where units of the antiaircraft artillery school, Camp Davis, N. C., work out field problems

The spiral-four system comprises spiral-four cable and *CF*-1 and *CF*-2 carrier equipments. The spiral-four cable consists of four spirally wound conductors with a common metallic-foil shield used as a common ground return having balancing coils and capacitors at quarter-mile intervals, thus loading the cable uniformly as a transmission line. *CF*-1 carrier equipment provides four voice-frequency channels over the spiral four. The addition of the *CF*-2 carrier equipment provides four telegraph channels over one of the voice channels mentioned previously. It is of interest to note that the production to date of *CF*-1 and 2 carrier equipment exceeds all *C*-, *H*-, and *K*-type carrier in use by the Western Electric Company and the American Telephone and Telegraph Company by 100 per cent. Later I will discuss the application of this same carrier system in conjunction with radio-relay systems.

As the major items of radio equipment in use by our field troops in 1940 we find the *SCR*-131, 161, 171, 193, 245, 194, 195, and 177. The *SCR*-131, 161, and 171 were all continuous-wave telegraph master-oscillator sets. These sets were perhaps good enough sets, their design being only five to ten years old, but since the time of the initiation of their design tactical operations had so changed that telegraph communication within the lower units, for which these sets were designed, was no longer a practical method of communication. It was, therefore, necessary to replace these three sets with simply operated voice-frequency sets.

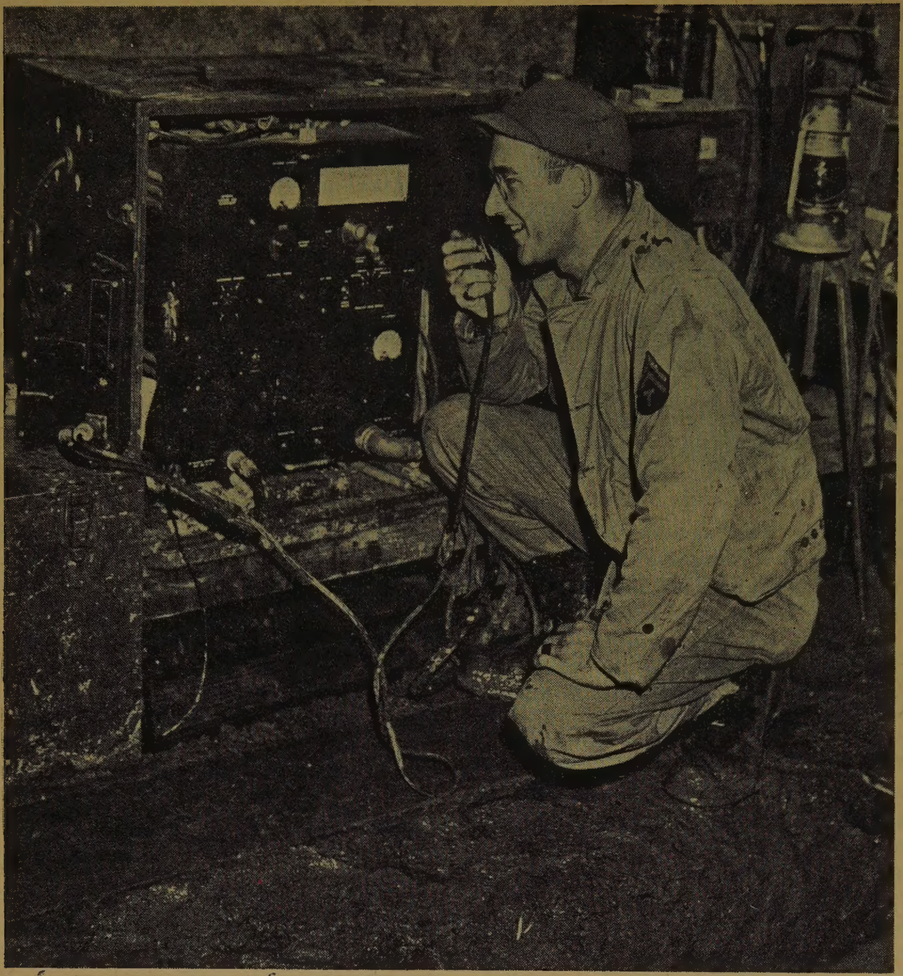
The *SCR*-193, which has the *BC*-191 transmitter (the same transmitter used in aircraft) and the *BC*-312 superheterodyne receiver, was somewhat old in design, the transmitter having been originally used on the Dole-Hawaiian flight in 1928. However, this transmitter was an item of aircraft equipment, and therefore money had been obtained for its redesign and improvement. Furthermore, so many transmitters had been built for aircraft use that all the bugs had been taken out of it. It was, however, a master-oscillator power-amplifier job and could not be netted without the use of a crystal-controlled frequency meter. The receiver that went in this set was a superheterodyne designed by the Signal Corps Laboratories that has stood the test of the war without major modifications. In fact, although we considered it necessary to replace the *SCR*-193 radio set, both transmitter and receiver, with the *SCR*-506, a modern radio set having 20-kilocycle crystal calibration points, four preset channels and one selective channel, our failure in this case to produce our new development in as good time as the rest of our developments does not seem to have affected our communications seriously. This is one case in which an old reliable of rather obsolete design has continued to give most excellent service. The 506 was designed for us by the General Electric Company. Captain O'Connell and Mr. Marks of the Signal Corps Laboratories contributed in an oustanding manner to the development.

The *SCR*-245 was of somewhat later design than the *SCR*-193 and had provisions for crystal control. However, it had only ten watts output and therefore was suitable only for relatively short-range work. Furthermore, although provision was made for crystal control during the life of this set, it was not possible to convince the using arms that crystal operation was desirable in this type of field equipment.

The *SCR*-194 and *SCR*-195 (the original walkie talkie) worked on by Captain Corput, Captain O'Connell, and principally by Mr. Hessel, were modern high-frequency superregenerative transceivers in the frequency band 28 to 65 megacycles.

The problem confronting the Signal Corps insofar as radio-communication equipment was concerned was to replace the tactically unsatisfactory and technically rather obsolete radio sets *SCR*-131, 161, and 171 for use within the regiment, to design a more suitable replacement for the *SCR*-193 for regimental and divisional use, and to provide a new mobile long-range vehicular radio set suitable for the so-called "blitz" tactics that occur from time to time in modern mechanized warfare.

Considering both wire and radio communication, the problem was to provide mobile communications to follow up divi-



Signal Corps photo

Figure 3. Radio Operator T/5 Howard R. Schneider at work on the SCR 543, Mignano area, Italy

sional troops using, where necessary, a combination of radio and wire.

In addition to the physical characteristics pertaining to combat communication equipment, there is another and most important factor in the design of communication equipment for combat use. That is the fact that the military communications necessarily must be organized on a command basis rather than on a common-user basis, that is to say, if we are to hold a commanding officer responsible for the operations of his command, we must furnish him with the necessary equipment with which to set up a communication system through which he will exercise command, and we must give him control of that communication system, because it is only by control of that communication system that he is enabled to conduct his operations.

This is not the case in commercial communications. In Dayton, Ohio, for instance, there is one telephone company that serves all of the people in Dayton and undoubtedly serves them most efficiently. This is true, because under peacetime conditions, since operations are very largely stabilized and since cheapness of service is a major factor, the communication system can be carefully laid out long in advance to provide efficient service to everyone concerned.

MILITARY ORGANIZATION EXPLAINED

In war, however, the commander must take into battle with him all of the equipment that he will need in battle and must rearrange and reorganize this equipment to meet his needs of the moment. For this reason military communications systems are organized to follow the chain of command; that is to say, we have the company communication system, which is operated by the company commander and which radiates from his headquarters.

Likewise, the battalion commander has his communication system which radiates from his headquarters down to the company headquarters. Similarly the division commander has his communication system which radiates from his headquarters down to the regimental headquarters. The corps communication system and the army communication system are organized in similar fashion.

Thus it is, generally speaking, difficult and sometimes impossible for the commanding general of an army to call up a platoon leader and tell him how to conduct his platoon during battle, and there is no need for such a conversation to take place, while there is every need for the company commander to be able to call up his platoon commander and tell him what to do next, and, since this need exists, the company commander must have the means to carry it out. It is obvious that no common-user system under the control of a single-battle-theater signal officer would be satisfactory to the company commander. However, in the rear areas the situation is generally more stabilized, and it generally will be found that greater and greater use is made of the common-user principle.

Taking up now the new front-line radio sets developed in this war, I will mention first those developed for the Armored Force: namely, the *SCR*-509/510 series and the *SCR*-508/528/538 series. The requirement here was for vehicular sets of range about three miles in the case of the 509/510 series and about ten miles in the case of the 508/528/538 series. The 508/528/538 problem was taken up with Mr. Lack and H. W. Ritter of Western Electric Company and Mr. Nelson and Mr. Nordahl of Bell Telephone Laboratory by Captain O'Connell, Mr. Marks, Mr. Ross, and Lieutenant Pollock of the Signal Corps Laboratories. In view of the need for rapid communication incident to modern front-line warfare, voice communication only was indicated, and furthermore it was necessary that communication be obtainable instantaneously and reliably. The main things to be decided were the frequency band, and type of modulation, the power output, and the number of readily available channels.

SELECT SUITABLE FREQUENCIES

As regards the most suitable frequency, we had two good leads. Over a period of several years we had had experience with the very low-power (perhaps one-tenth watt) radio sets *SCR*-194 and 195 in the band 28 to 65 megacycles, and, furthermore, we had run a series of tests over the band 2 to 80 megacycles in the fall of 1937 and spring of 1938 to determine the most suitable frequency for short-distance work. We also had the experience of the various city-police systems operating on 1.5 megacycles, 2 megacycles, and 38 megacycles. Strangely enough our experiments in 1937 and 1938 indicated that for vehicular communication purposes equally good results were obtainable on any frequency from about 2 to 80 megacycles if man-made interference was absent.

While I do not pretend to say exactly why this was found to be the case, nor even to argue very strenuously that it is the case, it may well be pointed out that such a result is not inconsistent with practical engineering facts that are well known to all of us. Since the practical height of an antenna on a vehicle is limited to 15 feet, the antenna efficiency of a set at only two megacycles is very low, whereas the antenna efficiency at 80 megacycles is very

Figure 4. T/4 David Kimmel with the United States First Army handles the switchboard where fire-direction orders are sent to two platoons on the line in Hurtgen Forest, Germany. Direction changes from the observation post also come through this board

Signal Corps photo

igh. On the other hand, the transmission haracteristics at 80 megacycles are such, t least theoretically, to give line-of-sight ransmission, whereas transmission on two megacycles tends much better to hug the ground and to get over the hills and down nto the valleys. Nevertheless, even two-megacycle transmission is to a certain exent optical when compared with still ower frequencies, and 80 megacycles is not high enough to be wholly optical, and ransmission at this frequency is also helped by the scattering effect of trees and rregularities of the ground and reflection rom various and sundry objects. The net esults of this is that the best vehicular requency in the band 2 to 80 megacycles is determined very largely by the elative absence of radio interference on any given frequency.

Tests made during the period 1937 to 940 indicated that from 2 to 20 megacycles interference from stations thousands of miles away was very severe.• In the egion 20 to 24 megacycles we found that here was still considerable interference, but we believed and it has since been proved that this band is quite usable for hort-distance low-power communication. From 24 to 28 megacycles there was almost an entire absence of interference. Since we already had radio-communication sets or ground troops in the band 1.5 to 5.5 megacycles and in the band 30 to 55 megacycles, we selected the band 20 to 28 megacycles for the Armored-Force sets. We had a little doubt as to the excellence of communications in this band, in view of our transmission experiments and in view of the excellent communications being obained on 38 megacycles by police radio equipment that had recently been introluced in a number of cities and in the Connecticut State Police system.

FREQUENCY AND AMPLITUDE MODULATION

As to the type of modulation to be used, we were in somewhat of a quandary. Some of our people had witnessed a demonstraion of frequency modulation given by the General Electric Company in 1938 and were convinced that this was a superior ype of communication for military vehicular use. Frequency-modulation equipment also had been introduced in the Connecticut State Police system and was being considered by some of the larger cities to eplace amplitude-modulation communication equipment.

For the 1939 demonstration at Fort Knox, which I have previously mentioned, Major Armstrong had furnished us with ome frequency-modulation communicaion equipment, and we had built at Fort Monmouth Laboratory a 50-watt frequency-modulation transmitter to give as good communication as ten watts of amplitude modulation. Nevertheless we hought the frequency-modulation principle to be sound and continued the deelopment during the fall of 1939 and during the spring of 1940 to the extent that we were able to do so with the few thousand dollars that we had.

In view of our uncertainty, we decided to proceed initially with the 508 series of sets on the basis of amplitude modulation, but immediately to make a comparative test of amplitude- and vehicular-modulation short-range sets. This test was made during the week of March 24 to April 2, 1941, and the results of the tests showed that frequency modulation in military vehicular application gave 50 per cent more range than amplitude-modulation equipment and up to midrange gave 100 per cent better communication. We had been somewhat concerned as to whether the so-called capture effect of frequency-modulation equipment would be a serious defect. However, we laid this ghost by actually trying out the capture effect. Since actual experiments, conducted under very well-simulated field conditions, showed this effect for military purposes to be practically nonexistent, we were much relieved and went ahead with frequency modulation.

At a later period in 1942, this question as to the value of frequency modulation was raised again by our Allies. Extensive day and night tests were held at the Harrison Farm, N. J., comparing the operation of preset mechanical-tuning 2–8-megacycle amplitude-modulation sets with our 20–28-megacycle frequency-modulation crystal-controlled sets. Witnesses of the tests were members of the British Military Mission, the Army Communication and Equipment Co-ordination Board, Ground Forces, the Chief Signal Officer, and representatives from the various staff divisions of his office. Tests were run during thunderstorms and pouring rain. These tests were supervised by Lieutenant Colonel Maier of the Signal Corps Laboratories and Colonel Elsdale of the British mission. The only open question remaining was operation over really rugged country and the effect of sunset and sunrise fading. Tests were held at Bethlehem, Pa., over a triple range of mountains covering the periods of dawn and sunset during the month of November of 1942. These tests were witnessed and recorded and proved conclusively that the frequency-modulation sets were the best.

This transmission problem is still being argued out in other circles on a theoretical basis with diminishing emphasis. So far as I am concerned there is no argument left, because we now have had approximately 200,000 frequency-modulated sets in satisfactory operation in bands above 20 megacycles.

As I have stated one of the problems that confronted us at this time was to decide the type of frequency control to use. It had been axiomatic in the military service that radio sets must be simple and rugged. It had also up to this time been axiomatic in both military and commercial circles that crystals were relatively unobtainable jewels of great price.

CRYSTAL-CONTROLLED SETS PROVIDED

Furthermore both the Navy and our Air Corps had tried combat types of crystal-controlled radio sets and had found them unsatisfactory. Having followed this problem for some years, I became convinced that the crystal-controlled sets had been unsatisfactory in the Navy and in the Air Corps, principally because not enough crystal-controlled channels were provided in each set and because crystals for all channels were not provided with each set. We, therefore, decided to provide ten preset crystal-controlled channels in each transmitter and to furnish 80 crystals with each transmitter.

At this time, we were fortunate in dealing with a man who believed in frequency modulation and who believed in crystals, namely, Fred Lack of the Western Electric Company. I am glad to say that Mr. Lack and his organization delivered an amplitude-modulated model of the 508 in

February and a frequency-modulated model in March of 1941 and actually started the wheels of production rolling before the set was formally standardized and all this before a contract of any kind had been approved.

Simultaneously with the Western Electric development of the *SCR*-508 our own laboratory engineers under Captain O'Connell, Mr. Hessel, and Mr. Morf proceeded with the development of the *SCR*-509, a frequency-modulation set with two preset crystal frequencies and 40 crystals in the same band as the 508 (20–28 megacycles), and, after completion of the design, this set was put in the good hands of Doctor Noble and the Galvin Manufacturing Company for production.

A further statement on crystals is in order. In World War I there was no mass production of vacuum tubes. They were handmade and nonuniform in operation. Our type numbers were formed from them; namely, the *VT*-1 and 2. The first miniature tube was the *VT*-5. By the end of the war, they were being produced by the tens of thousands. In this war, crystals were being produced on a hand-to-mouth basis by just six suppliers, all of whom considered the art a fine art and to be paid for accordingly.

Naturally, to implement the idea of crystals for every channel, aggressive steps were in order to provide the necessary quantity of crystals. With the help of civilian specialists and personnel who did not believe in superstition, such as Doctor D'Eustachio, Miss Grady, Major Woods, Captain Mitchell, Mr. Bell of War Production Board, Mr. Buff of Metals Reserve, Colonel O'Connell, Mr. Parrish of the Office of the Chief Signal Officer and later Doctor Van Dyke and Major Swinnerton, a crystal school for manufacturers was set up at the Steinbach Building, Long Branch, N. J., and a crystal-sorting plant at Bethlehem, Pa., was established, with the result that ultimately we obtained 14 crystals per pound from 30 per cent or better-quality quartz as against one crystal per pound at the peacetime level. The Bliley Company gave whole-hearted support to producing smaller crystals, and furnished us the first *FT*-243's. Bell Laboratories, under Doctor Bauer, and D. K. Martin, became enthusiastic over the *FT*-241. The crystal business was conducted from well-equipped shops to individual operators working in their houses throughout the farm lands of Pennsylvania, finishing crystals.

The crystal production today in one day equals the total annual crystal production in 1939. The number of crystals produced begins to approach the vacuum-tube production. The uniformity and accuracy of military crystals compared extremely well with industrial precision-ground crystals prior to the war. It was at this time that we had missionaries on the road with portable oil baths, X-ray machines, instruction books, and so forth, to preach the gospel of mass production of crystals. We all know the story now. To date the Army has spent $200,000,000 for crystals.

Mr. Galvin likes to tell the story that when selected as the manufacturer of the *SCR*-536 set he asked how he was to get the crystals, I told him he was an industrialist and that it was up to him to be industrious, not me. Well, he has been quite industrious and since that date has delivered millions of *FT*-243 crystals (with the help of 20 subcontractors) to the Army. However, it is well to mention the Western Electric Company who has delivered more than half as many *FT*-241 crystals from their own shops.

These sets, the *SCR*-508 series and the *SCR*-509 series, were sets for the Armored Force. The *SCR*-608 and *SCR*-609 series were similar sets later designed for the Field Artillery. The successor to the 609; namely, the 619, which is two-thirds the size and weight of the 609, is going into production to replace the former set.

In the Infantry there was need for quite a different type of set: namely, one weighing only a few pounds that could be used farther forward, even though the communication range might be only a few hundred yards to a half mile. In the fall of 1940 Mr. Mitchell of the Galvin Manufacturing Company came to us with the solution of this problem, and the result was the *SCR*-536, a single-channel crystal-controlled amplitude-modulated set covering the low-frequency band. We had tried many master-oscillator sets of this category, but none was satisfactory, because when you get down to a set of this size there is simply not room to build stability into transmitter and receiver circuits. Mr. Galvin, of course, got the contract for this set and again had to be quite industrious about getting out crystals.

At this time the Infantry division also required a combination vehicular–field set in the frequency band 2.8–6.5. The requirements as given to us by the Chief of Infantry were very severe. One day in early October of 1940 Mr. Clement of the Crosley Corporation came to call on me at the Fort Monmouth Laboratory and stated that his company was considering going into national-defense business and that they were anxious to obtain a development contract for radio equipment. At first I told him that I was sorry that he was too late, that we had 19 radio sets to be developed at once; that we were developing one ourselves and that the other 18 had already been contracted for. At this time we had already endeavored to peddle the *SCR*-284 development to all the radio manufacturers in the country that we could lay our hands on, but none had been willing to undertake it, and I had to give it up as a bad job.

SCR-284 DEVELOPED

Just as Mr. Clement was leaving I remembered our white elephant and called him back and told him that the job was so tough that I did not believe he would be interested, but he undertook the development, and the Crosley Company delivered the first production set in March of 1942, and since that date many thousands of *SCR*-284 sets have been delivered. This set is two packages weighing 35 pounds each, being powered either by battery or hand generator, having both a whip and fixed-length antenna wire, for code and voice transmission.

A lighter-weight successor to the 284, the *SCR*-694, already was on the way soon after the deliveries of the first set. This set was to be moistureproofed and practically indestructible. The 694 was given to Mr. Rauland to produce. Mr. Rauland was assisted in his growing pains by Captain Vanderveer and Captain Ray Morris. It will be noted that we did not use crystal control in this set, but used a crystal calibrator. Without going into the reasons for this, I may state that, although I am an advocate of crystal control, crystal control is not the answer to all problems.

While discussing the radio equipment for an Infantry division I must necessarily now make a diversion to the Cavalry. In the fall of 1940 the Cavalry needed a lightweight radio set that could be carried readily by a trooper and used either on horseback or on the ground. Together with Captain McBride, who was our Cavalry liaison officer, we conceived the idea of building a radio set in the middle of its antenna so to speak. The result was the

Signal Corps photo

Figure 5. A five-man infantry patrol looks for snipers as they move to take the town of Libin in Belgium. Soldier at left carries bazooka in arms; man on far right transmits message to rear with "walkie-talkie" pack radio outfit

SCR-511 in the medium-frequency band. This set is carried by the trooper in exactly he same manner that he carries his guidon; hat is to say, the lower end of the antenna s in the stirrup boot. The trooper is provided with a chest set which acts both as a microphone and as a loudspeaker. Again, because of its small size, it was necessary to make this set crystal-controlled, and in this case we provided 20 crystals per set.

Captain James D. O'Connell and Capain McBride always pictured the *SCR*-511 on board a horse. It has been used everywhere but there. Captain McBride did est the set for fragility when rolled on by he horse. He did not, however, test the attempts of the infantrymen to plant the antenna as a flagstaff with one blow of the hand. The Infantry comes into this picture because, when the sets were delivered, higher authority decided that the Infantry divisions needed the sets more than the Cavalry. Consequently, this set has become a standard Infantry-division set, and he Cavalry actually received nothing more han service-test models until after many housands of sets had been delivered for Infantry-division use.

As I have already stated, there was also a need to replace the *SCR*-195 in the Infantry division, but this proved to be a much tougher problem. The *SCR*-195, hough obsolete in principle, had been so well designed and manufactured that we had to wait $2^1/_2$ years to replace it. Over a period of eight years after the design of he *SCR*-195 we tried forestry sets, Navy ets, sets manufactured for the South American republics, and many others, and ried our own hand at redesigning a set to upersede the *SCR*-195, but were not successful.

FEATURES OF WALKIE-TALKIE

Finally, in 1942 development contracts were given to six different firms, all with lightly different directives, and the *SCR*-300 (the present frequency-modulation walkie talkie) combined the best features of all of them. This set was turned over to Doctor Noble of the Galvin Manufacturing Company to produce. It was waterproofed, fungus-proofed, practically indestructible, and weighed only 32 pounds, complete with battery. The set is not crystal-controlled but has a crystal calibrator and a very effective automatic frequency control in the receiver which enables it to be successfully netted in spite of he lack of crystal control. This was done at the expense of considerably widening he channel spacing as compared with the 508 series of sets, the *SCR*-300 using a channel spacing of 200 kilocycles as compared to 100 kilocycles for the 508 series.

It too had its growing pains in that iniially our miniature tubes were not rugged enough for this set. E. W. Ritter, Captain Trenary, and Lieutenant Colonel Maier were a special committee to improve the miniature-tube business rapidly. This was done by interchanging the best factory techniques among the various producers of miniatures. Mr. Ritter contributed immensely in reducing the glass shrinkage by making stress-and-strain studies of the base and the glass involved. Shrinkage was cut from 80 to 10 per cent in the factory and from 40 to 3 per cent in the Government service.

Thus far we have considered only point-to-point radio-communication operation in nets. By reason of rapid movement of a mechanized army, the troop movement would soon outrun the wire system. To handle this situation we have provided a highly mobile long-range radio set in its various forms known as the *SCR*-299, 399, and 499, and we have also provided a radio-relay system. A forerunner of the 299/399/499 series was the *SCR*-299.

In the fall of 1940 we secured a number of models of commercial types of radio transmitters varying in power from 200 to 500 watts and after comprehensive tests selected the Hallicrafter *HT*-4 transmitter as the commercial job best suited for our purpose. Working with the engineers of that company Colonel O'Connell, Captain Soules, and Mr. Jipp of the Signal Corps Laboratories strengthened and modified the *HT*-4 to make it more suitable for military operations and mounted it in a $1^1/_2$-ton truck together with two superheterodyne receivers of the Signal Corps Laboratories' design, a trailer power unit, and a number of additional accessories.

This set takes care of the situation when the Armored Forces outrun all other types of communication, and in addition it is used as a substitute during initial operations for almost any kind of fixed radio installation that may later be installed. Its popularity and suitability are attested by the fact that in going through any of the theaters of operation one has a feeling that he is surrounded by 299's, 399's, and 499's.

Speaking of our radio program in general, the introduction of frequency modulation in appropriate cases greatly improved communications by minimizing the effect of static and ignition and other vehicular noises. Colonel O'Connell at an early date became convinced of the necessity also of applying radio-suppression measures to all military vehicles, because in a column of trucks interference comes not only from the radio-equipped vehicle itself but also from the vehicles in front and behind and those passing by. Early pioneering assistance in this matter was given us by Ray C. Ellis of Delco and a competent group of Delco engineers. This work was followed up by our establishment of a vehicular radio laboratory in Detroit, and by co-operation with the Ordnance Department and the automobile manufacturers we have been able to establish a complete suppression program.

The radio-relay system originally called the radio-link equipment, was accumulated in the summer of 1941, and that fall a demonstration was given in the North Carolina maneuvers by Major O'Connell, Mr. Marks, Mr. Hessel, and others, to demonstrate the principle of main-axis communication by means of repeaters. This equipment is now known as the *AN/TRC*-1 and is again a frequency-modulated equipment in the high-frequency range of 70–100 megacycles, using beamed antennas. The successors to it for special purposes are underway—the *AN/TRC*-5, 6, and 8, all equipped for carrier operation, both voice and telegraph. In addition, an amplifier has been worked out for the *AN/TRC*-1 to extend its range.

The utility of this type of equipment was not recognized until it was shipped to North Africa in the spring of 1942. Captain Perkins and five engineers from the laboratory did yeoman service in furnishing emergency communication during the Tunisian campaign. During the Sicilian and Italian campaigns, its utility was fully recognized. The original equipment consisted of 50-watt Motorola sets with vertical antennas and was intended only as a single-channel voice-relay system. The *AN/TRC*-1 first was used in quantity in the invasion of Normandy and the current campaign in France. Mr. Waite and Mr. Calagouri of the Camp Coles Signal Laboratory accompanied the equipment and rendered valuable service to the armies in France. It is difficult now to meet the requirements for this type of equipment. It is believed that this type of communication will be normal procedure in the opening phases of any meeting engagement, to be succeeded in the later phases by field wire and then by spiral four.

The integration of wire and radio equipment is becoming closer daily. Unfortunately, whereas the radio industry talks in terms of pounds per watt, the telephone industry is still on the basis of pounds per milliwatt. Rapid strides are being made in the development of a comparable lightweight system by the wire-communication industry. With the full utilization of sound power in voice communication, the radio will be pushed to maintain its lightweight leadership.

DEVELOPMENT ALLIED WITH PRODUCTION

Though I have dealt only with development, development can never be disassociated from production, and in the early days the two went hand in hand. Through the co-operation of our contractors and with the help of the Radio and Radar Division of the War Production Board under the leadership of Ray C. Ellis, Colonel Elder, assisted by Mr. Lack in Army–Navy Electronic Production Agency and the procurement districts under General Farmer, Colonel Daw, and Colonel Corput, managed to boost Signal Corps ground- and air-equipment deliveries from \$12,000,000 for December 1941 to \$175,000,000 for December 1942, and the \$175,000,000 in equipment delivered during December 1942 was modern equipment.

Standards for Steam Turbine Generators

THE JOINT COMMITTEE on Steam Turbine Generators was established by the board of directors of AIEE and council of American Society of Mechanical Engineers to prepare preferred standard ratings and characteristics of steam turbine generators.

The objective of the Joint Committee was the establishment of standard ratings and characteristics of steam-turbine-generator units that would closely fit the requirements of purchasers, the selection of operating pressures and temperatures for each standard unit, and the fixing of standard extraction temperatures for the various units. General acceptance of the standards should result in reduced prices and shorter deliveries than for nonstandard machines and should permit of a decrease in time required by manufacturers to submit performance estimates.

These standards in no way will prevent the purchase of any size of steam turbine generator that is desired for any set of operating conditions different from those indicated in these standards, but such units may not have the benefits expected to accrue through use of the standardized units. Further, the standards are not intended to prevent the purchase of duplicates of machines already installed and for which designs, patterns, and the like, are available.

The preferred standards are intended to be progressive standards and to permit technical and economic development, consistent with the fundamental purpose of expediting production and installation of steam-electric generating equipment. To that end they should be reviewed, at least annually, and as occasion seems clearly to warrant, to determine whether advances in the art call for specific modification. Standardization is not expected to stifle development but, on the other hand, should make available more effort for improvements and research work.

Standardization of steam turbine generators and their extraction conditions should permit, to a degree, similar standardization of steam-producing equipment and accessories, piping, condensers, extraction heaters, make-up evaporators, and so on, all of which should tend to decrease first cost and time required for delivery and installation of equipment.

The initial activities of the Joint Committee have been confined to condensing units for operation at 3,600 rpm, between the ratings of 11,500 kw and 60,000 kw, the former being a logical first step beyond existing National Electrical Manufacturers' Association (NEMA) ratings and the latter representing the rating of tandem-compound machines with double-flow low-pressure elements equipped with largest last-row blades or buckets now available for 3,600-rpm service.

The Joint Committee consulted frequently with technical committees of the AIEE, Association of Edison Illuminating Companies, and Edison Electric Institute. Through these technical committees information has been received from operating companies having more than 18,000,00 kw of steam-turbine-generator capacity installed on their systems. This information has been of great value and has been utilized in the preparation of the standards.

The significant features of the standards shown in the attached tabulation of ratings and characteristics are:

1. Six standard unit ratings from 11,500 kw to 60,000 kw, inclusive.

2. One or two standard values of throttle pressure and temperature for each rating.

3. Definite number of extraction openings for each machine, with specified values of saturation temperature at each opening when operation is at turbine-generator rating with full extraction from all openings.

4. Specification that the guaranteed turbine capability, in kilowatt output at the generator terminals, shall be ten per cent above the turbine-generator rating of each unit, instead of the 25 per-cent margin usually provided in the past.

5. Specification that the power-factor rating of the generators shall be 85 per cent at the generator rating, and yet provide greater kilovolt-ampere capacity in proportion the capability of the turbine than in prese designs; also that the short-circuit ratio the generators shall be 0.8 at generator ratin

6. The two smaller units will have ai cooled generators, whereas the four larg sizes will have hydrogen-cooled generator the latter rated for normal operation wi 0.5 pound per square inch gauge hydroge pressure and with 15 per cent addition kilovolt-ampere capability above generat rating provided by increasing the hydroge pressure to 15 pounds per square inch gaug

It is recommended that purchase consider use of these preferred standar in procuring new steam-turbine-generat capacity.

The personnel of AIEE–ASME Joi Committee on Steam Turbine-Generato is as follows:

Representing AIEE. M. S. Oldacre, *chairman;* F. Brown, R. P. Crippen, E. S. Fields, H. S. Fitch, J. Foote, C. M. Laffoon, J. B. McClure, S. H. Mortense Stanley Stokes.

Representing ASME. K. M. Irwin, *chairman;* R. Allen, C. B. Campbell, A. G. Christie, G. A. Gaffe E. H. Krieg, A. L. Penniman, Jr., W. F. Ryan, G. Warren.

STANDARD SPECIFICATION DATA FOR GENERATORS

In addition to the afore-mentione standards for turbine generators, whic were prepared by the Joint Committe standard specification data for generato have been prepared by the AIEE grou of the Joint Committee. The data cove detail information that will assist in th standardization of the generators.

The standards and the standard spec fication data will be available in a sho time as regular publications of the societie

Preferred Standards for Large 3,600-Rpm Three-Phase 60-Cycle Condensing Stea Turbine-Generators

		Air-Cooled Generator		Hydrogen-Cooled Generator			
				Rated for 0.5 Pounds Per Square Inch Gauge Hydrogen Pressure			
1.	Turbine-generator rating—kilowatts	11,500	15,000	20,000	30,000	40,000	60,000
2.	Turbine capability—kilowatts	12,650	16,500	22,000	33,000	44,000	66,000
3.	Generator rating						
	Kilovolt-amperes	13,529	17,647	23,529	35,294	47,058	70,588
	Power factor	0.85	0.85	0.85	0.85	0.85	0.85
	Short-circuit ratio	0.8	0.8	0.8	0.8	0.8	0.8
4.	Throttle pressure—pounds per square inch gauge	600	600	850	850..850 } or	{ 1,250..850 } or	{ 1,25
5.	Throttle temperature—degrees Fahrenheit	825	825	900	900..900 }	{ 950..900 }	{ 95
6.	Number of extraction openings	4	4	4	5	5	5
7.	Saturation temperatures at openings at "turbine-generator rating" with all extraction openings in service—degrees Fahrenheit: 1st	175	175	175	175	175	175
8.	2d	235	235	235	235	235	235
9.	3d	285	285	285	285	285	285
10.	4th	350	350	350	350	350	350
11.	5th				410	410	410
12.	Exhaust pressure—inches mercury absolute	1.5	1.5	1.5	1.5	1.5	1.5
				Operated at 15 Pounds Per Square Inch Gauge Hydrogen Pressure			
13.	Generator capability at 0.85 power factor—kilovolt-amperes			27,058	40,588	54,117	81,176

A tolerance of plus or minus ten degrees Fahrenheit shall apply to above saturation temperatures. (Tolerances sha be unilateral so as not to reduce the spread in temperature between adjacent extraction openings.)

"Turbine capability" is guaranteed continuous output at generator terminals when the turbine is clean and operatin under specified throttle steam pressure and temperature and exhaust pressure, with full extraction from all extractio openings.

Essential substance of "Preferred Standards for Large 3,600-Rpm Three-Phase 60-Cycle Condensing Steam Turbine Generators (Larger Than 10,000-Kw Rated Capacity)." This Standard has been prepared and approved by the Joint Committee on Steam Turbine Generators of AIEE and the American Society of Mechanical Engineers and will be published by the Standards committee at a future date.

Statistical Methods in Quality Control

I. Variability of Quality—Frequency Distributions

This first of a series of articles on statistical methods in quality control, prepared by the AIEE subcommittee on educational activities and sponsored by the AIEE subcommittee on statistical methods, discusses the use of frequency distribution in the regulation and control of variability of quality and the conclusions that may be drawn from it.

THE AIM of the manufacturer of electric apparatus and equipment is to eproduce the same thing again and again. ut as in the mechanical and other fields e recognizes that it is quite impossible o make two things exactly alike. Even ith the best-known means of regulating aw materials, production machinery, nd manual operations, he will find that here are always measurable differences in he individual articles turned out by the roduction process. Thus one of the basic haracteristics of quality—its variability— s something that we never can get away rom, but statistical methods can be helpul in regulating and controlling it, from rticle to article, from machine to machine, rom day to day, and so on.

GRID POTENTIAL IN VOLTS		FRE-QUENCY	FREQ. IN %
-4.7 TO -4.6	||	2	3.3
-4.5 TO -4.4	||	2	3.3
-4.3 TO -4.2	||	2	3.3
-4.1 TO -4.0	𝍸	5	8.3
-3.9 TO -3.8	||||	4	6.7
-3.7 TO -3.6	𝍸 |||	8	13.3
-3.5 TO -3.4	𝍸 𝍸 |||	13	21.8
-3.3 TO -3.2	𝍸 |||	8	13.3
-3.1 TO -3.0	𝍸 ||||	9	15.0
-2.9 TO -2.8	𝍸 |	6	10.0
-2.7 TO -2.6	|	1	1,7
	TOTAL	60	100.0

igure 1. Building up a frequency disribution by classifying the measured values

Suppose we were to take a batch of some 0 power thyratrons and measure the ritical grid potential on each of them nder a standard test procedure. This roup of 60 measurements might look omewhat as shown in Table I. We notice hat although we would like to make this ritical voltage the same for all of the ubes, the individual values vary from unit o unit. Recognizing that some variability s unavoidable in repetitive manufacture, he designer normally includes in his speci-cations certain limits within which the ritical voltage must fall (−4.8 volts ninimum and −2.3 volts maximum in this ase) in order that an individual thyratron vill be satisfactory for the service for which t is intended.

We can scan this mass of numbers, but e do not get much of a picture of the tuation as a whole since there is just too nuch for the mind to comprehend at a lance. All that needs to be done is to choose, as in Figure 1, some suitable class intervals of equal width and then make a tally in the proper class or "cell" for each of the measured values shown in the table. The result is a *frequency distribution*, the term frequency here denoting *frequency of occurrence*.

From such a distribution, we quickly get a picture of certain features of the group quality of this batch of 60 thyratrons, such as

(*a*). The approximate central value or *average*.

(*b*). The spread or *dispersion* of values.

(*c*). The relation of the quality of the batch as a whole to the specified minimum and maximum limits.

Figure 2 presents this same information in a somewhat more formal manner, together with the results of measurements of specific quality characteristics for various other electrical products. All these diagrams give the same general story, namely, a considerable amount of variation in quality from article to article. All the diagrams show a bunching of values near the middle and a trailing off toward the extremes.

Just what does such a frequency distribution reflect?

First, it provides a condensed description of the group quality of the particular set of *articles tested.* Second, if we also had the qualitative information that this particular set of articles was a sample selected at random from a large production lot, then the frequency distribution provides us with information regarding the quality of the *lot* as a whole, which includes both tested and untested articles. Third, and more important still under these conditions, the distribution provides a quantitative picture of the production *process* itself at the time of manufacture of the particular lot which this sample represents. The variation, for example, in grid potential of the thyratrons tested reflects the many causes

Table I. Measurements of Critical Grid Potential in Volts on 60 Low-Voltage Power Thyratrons

−3.5	−2.6	−4.7	−3.5	−2.9
−3.6	−2.8	−4.2	−3.2	−3.1
−4.0	−3.2	−3.2	−2.8	−2.6
−3.4	−3.8	−3.1	−3.4	−3.7
−3.2	−3.4	−3.0	−3.0	−4.1
−3.5	−3.5	−4.1	−3.1	−2.9
−3.5	−3.9	−4.0	−3.6	−3.1
−3.6	−3.3	−3.2	−3.9	−4.6
−3.4	−3.3	−2.8	−3.6	−2.9
−3.3	−4.5	−3.4	−3.1	−3.1
−3.4	−4.3	−3.4	−3.9	−3.6
−3.0	−4.4	−3.5	−4.1	−3.6

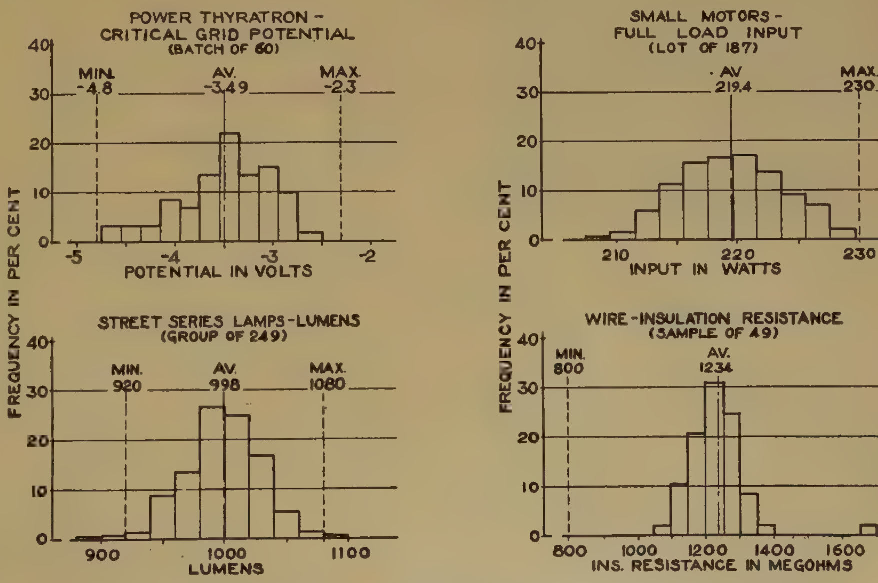


Figure 2. Frequency distributions of individual quality characteristics

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ersonnel of the AIEE subcommittee on educational ctivities: J. Manuele, H. F. Dodge, A. I. Peterson, nd R. E .Wareham.

of variation in this characteristic contributed by materials, machine operations, and manual operations. If the distribution is poorly located with respect to the specified limits, this then may be taken to indicate the need for some corrective action on the process itself. Fourth, if we knew that this distribution represented measurements made on a whole series of random samples from a series of production lots and that the results of this series of samples had been found to exhibit "statistical control," then this information would allow us to predict within limits what we could expect in future product made by the same controlled process. This is a desired goal for many technica products.

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Dual A-C Network Calculator

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A new network calculator with two independent master instrument and control desks affords means of conserving time of operation and obtaining greater accuracy for large complex systems.

STUDIES of electric-power-system expansion and changes for war needs have been speeded up by the use of a new network calculator. This new calculator is twice as effective as previous ones, because the simultaneous solution of two independent networks is possible for large complex systems involving high-voltage trunk lines and low-voltage networks which if put on a common base would handicap accuracy of readings because of extreme wide limits of power quantities. By means of two instrument desks and suitable selector switches for the various component elements of the calculator, the large complex system can be broken up into two independent systems as may be found desirable.

The enlarged and improved calculator is a product of knowledge acquired from more than 500 system studies on earlier designs and experience gained in the construction of calculators for public utilities and other concerns operating extensive electric networks. This new calculator provides improved mechanical and electrical features which result in increased speed of operation, higher accuracy, and greater convenience to the user than previous designs. The outstanding improvements are:

1. Two instrument desks which permit simultaneous working of two problems.

2. Increased number and range of circuits which represent the corresponding parts of an actual system.

3. Improved metering facilities which include instruments with scales such that actual power-system quantities are read directly without using multipliers.

4. Instantaneous electrical selection of any circuit for metering purposes with pilot lights indicating which circuit is being metered.

5. Location within easy reach of the operator of all devices such as generator and load units, which have to be adjusted during the course of a problem.

Every element in a power system has its counterpart on the network calculator. In addition to portraying electrically such concrete objects as a 100,000-kw generator or a 200-mile transmission line, network-calculator circuits can represent such abstract concepts as the zero-sequence mutual inductance between a pair of feeder circuits. The number, type, and range of the various circuits is indicated in Table I.

With this number and range of adjustable values, the calculator can represent power systems varying in size from that of the modern airplane network to th largest system interconnection coverin many states. At one time a resistor-reactor element may represent only 10 feet of cable and yet at another time b used to reproduce a 100-mile section o line.

A general view showing ten of the 1 steel cabinets and one of the two instrument and control desks is shown in Figur 1. Right behind the meter-desk operato are located the 18 generator units wit their associated voltmeters, ammeter wattmeters, and controls. Voltage an phase-angle control of the generator unit are independent of one another. Voltag adjustment corresponds to excitatio changes in the actual system and phase shifter adjustment corresponds to change in the governor setting of the actua system. The generator internal impedances are low-loss reactors with a sufficien range to represent subtransient or synchronous reactance of the generators.

Table I

Number	Type	Purpose	Range	Steps
18	Generator units	To represent generators or phase-shifting transformers	0–440 volts	Smooth
			0–360 degree angle	Smooth
18	Generator reactance unit	To represent generator reactance	0–499 ohms	0.2
152	Line-impedance units	To represent line impedance and transformer reactance	0–399 ohms resistance	0.2
			0–301 ohms reactance	Smooth
48	Load-impedance units	To represent shunt loads	0–3990 ohms resistance	2
			0–2400 ohms reactance	Smooth
48	Load-adjustor units	To maintain constant load	±10 per cent	1 per ce
48	Capacitor units	To represent line-charging-capacity synchronous condensers, negative reactance	0–4.1 microfarads	0.01
36	Autotransformer units	To represent transformer taps	±10 per cent	1 per ce
36	1/1-ratio two-winding transformers	(*a*). To permit representing mutual induction between parallel circuits when connected as 1/1 ratio, or (*b*). To permit using two or more kilovolt-ampere bases simultaneously for extended range problems when connected as a 2/1 autotransformer between parts of the complete network		
48	Meter jumper circuits	For bus connection and totalized metering		

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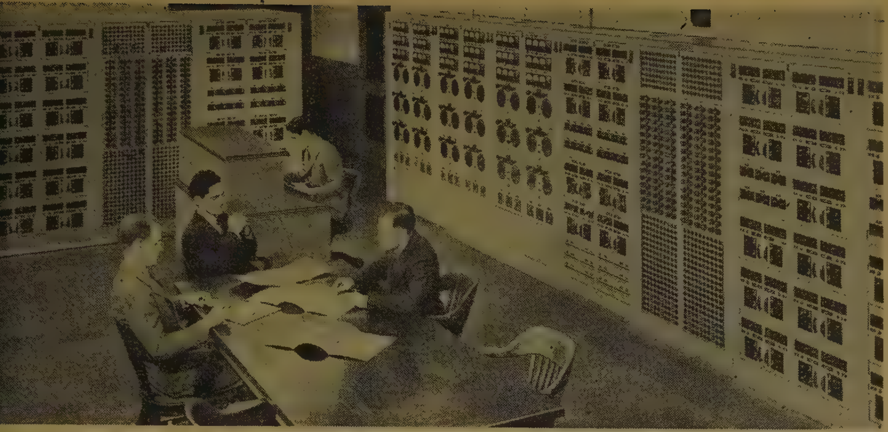

igure 1. **General view of calculator room showing steel cabinets containing circuit elements, control desk, and work table (in foreground)**

The load circuits are equipped with eans for connecting the resistance and eactance elements either in series or in arallel, so that with the same resistance nd reactance circuit a range of loads of 00 to 1 can be represented. The load djusters are autotransformers perma- ently connected in series with the load nits. With these units the power and eactive kilovolt-amperes drawn by a ad unit can be maintained at a constant alue even though voltage on the load nit may vary over a wide range during a eries of studies.

The condenser circuits are adjustable ver a sufficiently wide range so that one rcuit element can represent the line-harging capacity of the smallest line sec- on or a large synchronous condenser. he autotransformers can represent regu- ting transformers as well as the main ansformer tap of power transformers.

The combination 1/1-ratio two-winding r 2/1 autotransformers are new units hich have been added to the calculator nd replace the older 1/1-ratio transform- rs formerly used only to assist in represent- g mutual induction between parallel rcuits. When connected as 2/1 auto- ansformers they permit using two kilo- olt-ampere bases for a single network hat is not too involved and yet needs one ase for high-voltage high-power circuits nd a lower base for low-voltage lower- ower portions of a combined system. his is an intermediate step to separating ne network into two independent systems nd operating the two master instrument esks simultaneously. The characteristics the particular system determine which ethod is better suited. When the 2-to-1 ansformers are used, the high-voltage ystem is operated at twice the voltage the low-voltage system, and, conse- uently, lower impedances and higher urrents can be used on the low-voltage art of the network, thus extending the ange of readable values.

All circuit elements are mounted in rawers which can be withdrawn readily o facilitate inspection (Figure 2).

The calculator circuits can be connected to either instrument desk by an instantaneous circuit selector controlled from a 26-button keyboard mounted on each instrument desk. By pushing three keys the desired circuit is immediately connected to the instruments. Two independent sets of instruments are provided on each instrument desk so that the actual system quantities can be obtained in the most directly useful terms applying to the specific study. Direct readings in calculator quantities can be obtained in volts, amperes, watts, vars, and phase angle. The voltages and currents can be metered in scalar values, vectors, or as components with respect to any selected reference. Losses can be obtained directly. For most voltage-regulation studies the scalar voltages and the power and reactive kilovolt-amperes are the most useful quantities. In this case only two instruments are used, the voltmeter and a combination watt–var meter which gives these readings direct. Reading of actual system values has been achieved by equipping the instrument with a scale selector which permits choice of a scale in accordance with the kilovolt-ampere base. With system bases of per cent or per unit on 10,000, 20,000 or 40,000 kva the actual system quantities can be obtained directly without the use of any multipliers except setting of decimal points. The numbers on the scales are changed in accordance with the base being used.

The physical arrangement of the new calculator and the mechanical and electrical details are designed to provide maximum production as measured in terms of calculator data per hour. Individual circuits are so arranged that the units which require adjustment during the course of a study, such as generator units or load circuits, are located close to the operator at the instrument desk. In addition, remote control is provided for the generator units which normally would be used with the second instrument desk. An independent set of generator instruments is mounted on this second desk, and with this remote control the operator has complete observation and means of adjustment of the units directly from the instrument desk. This remote control consists of key operation of small reversing gear motors connected to the generator-unit voltage regulators and phase shifter. One key provides for raising and lowering the voltage and another key for changing the phase shifter clockwise or counterclockwise.

All these new features have simplified the procedure in making studies. Certain time-consuming steps such as the conversion of network-calculator readings to actual system quantities have been eliminated. The steps to be followed with the new calculator are:

1. Assemble and arrange impedance and other data of the power system, preferably in the form of single-line diagram.
2. Convert these data to a common base, such as per cent on 10,000 kva, 20,000 kva, 40,000 kva, or decimal multipliers thereof.
3. Set up the network and adjust the loads and the generator inputs in accordance with the requirements of the specific problem.
4. Meter the network and record directly on the one-line diagram the significant calculator readings such as voltage, watts, and vars.
5. Analyze the results, and determine the best plans for solution of the problem.

In addition to the new electrical and mechanical features of the calculator, improved technique in operation and in presentation of results has been developed. The time required for the various steps in a solution has been reduced to a minimum. The efforts of the engineers conducting the study therefore can be utilized almost entirely in an analysis of results and planning the procedure to be followed for subsequent studies.

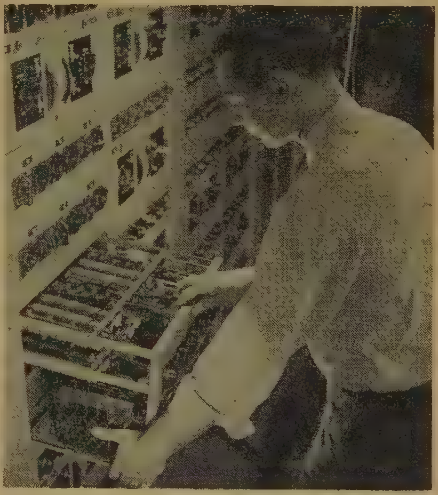

Figure 2. Draw-out-type circuits are readily accessible for inspection and maintenance

Grounding Principles and Practice

V—Static Electricity in Industry

ROBIN BEACH
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The hazards of fire and explosion are ever present in many industrial processes, awaiting only a spark to bring disaster—and static electricity can and often does provide the spark. The limitations of grounding as a universal remedy and the need for expert analysis of the problem are emphasized in this article, which is the last of five based on a series of lectures on the subject which was sponsored by the power and industrial group of the AIEE New York Section during the 1943–44 season.

INDUSTRY and the war effort are paying a large toll to static electricity in the cost of work stoppage and slowdowns, in the cost of property damage from fires and explosions, and most unfortunate of all, in the cost of injuries to personnel and in the sacrifice of human lives. The disturbing note in this situation of industrial sabotage lies not so much in the lurking evils of the cause itself as in the casual attitude with which industrial management, in general, seems to countenance these hazardous and costly nuisances.

The "mysterious" behavior and the destructive propensities of static electricity, under various circumstances, are fairly well known to those who have devoted years of specialized study to learning the characteristics of electrification and to devising tailor-made methods for its control. It is unfortunate for the initiate that he must discover for himself the large crop of confused, contradictory, and erroneous statements that lie buried in the literature of the subject. The many and glaring violations of electrophysical principles that have accumulated in the written word of this particular subject are probably the result of too much theoretical speculation and too little experimental evidence and practical knowledge.

Industry is finding itself confronted with a "two-barreled" program in combating the ravages of electrostatic sabotage. First the problems within the plants must be carefully segregated and analyzed, and then corrective techniques must be devised for and applied to each elemental problem, individually. Obviously experience and ingenuity are the investigator's chief assets in these experimental studies. The degree of success attained in an applied solution can be determined only by quantitative data as obtained from the application of proper instrumentation in testing. Secondly, and quite as important as the first, a comprehensive training program should be organized and administered by which the operating personnel is made alert to the nature of the electrostatic problems, to their particular hazards, and to the observance of every tenet in carefully prepared codes of maintenance and safety practices.

All of these schedules are the responsibility of management—first of having the electrostatic problems solved in the most capable manner possible, and secondly of seeing to it that they stay solved, by enlisting the co-operation of an effectively trained operating personnel.

IS GROUNDING THE PANACEA TO ALL ELECTROSTATIC PROBLEMS?

If the answer to the query were in the affirmative, all electrostatic ills could be readily cured by simply grounding the component parts of the offending machines or devices. Let us examine the general problems of how electrostatic hazards arise, and then deduce an appropriate reply to this question.

HOW ELECTRIFICATION ARISES

Electric charges, which always occur in pairs of positive and negative kinds, are brought into being when any two dissimilar substances are in contact. The negative charges—the electrons—migrate to one substance and their positive counterparts, in equal numbers, remain on the other substance. The number of charges thus developed in the substances depends upon the nature of the substances, the extent of area in actual contact, the temperature, the cleanliness of their contacting surfaces, and the pressure between them. In order to become aware of the presence of these charges, the substances are most commonly separated, and this process generally is referred to as generating static electrification. For the generation of an appreciable, or readily measurable, amount of electricity by such separation, at least one of the substances must be practically nonconductive. In this instance the charges become entrapped and impounded, during the process of their separation, upon the substances to which they became attached while the two substances were in contact.

The nature of the contact between the two component substances in most industrial operations is influenced by physical pressure, either with or without accompanying friction. The pressure may be light, as when paper or textile stocks travel over idler rolls; or the pressure may be great, as it is between the embossing rolls for imprinting wall paper, or as exists at the treads of automobile tires; or the pressure may be the result of zephyr-like contacts of finely dispersed powders such as sulphur, flour, and many others which are air-borne during transportation through parts of the manufacturing processes.

If one of the separating components, such as a machine part, is conductive, it should be grounded permanently in order to discharge itself continuously during its operation. Conversely, the nonconductive substance, that is, the product, retains its impounded charges, and when the electrified product becomes separated by its movement from the grounded machine part—as two charged plates of a capacitor might be moved farther apart—the voltage between them increases, enormously at first and about in proportion with the distance of their separation. But as the distance of separation becomes appreciable, the increase in voltage grows less and less, until finally further separation causes no additional voltage. Interestingly enough though, when two substances are firmly pressed together, they are still no nearer to each other than the dimensions of an atom—this being a separation of about 10^{-8} centimeter.

CONTACT DIFFERENCE OF POTENTIAL

At this inconceivable closeness of atomic dimensions, the electric forces within and between the atoms at the contiguous surfaces of both substances undergo such modifications and reorientation that boundary electrons are caused to pass from the surface atoms of one substance into those of the other. In this way the one substance becomes negatively charged while the other substance by losing electrons acquires an equal positive charge The principle that underlies this little-known process is the contact difference of potential theory.

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Investigations into this realm of theory have divulged some valuable and basic information on the subject of contact electrification. When a poorly conducting liquid makes contact with solid insulators or with metals or with other liquids, or when two solids are pressed into contact, that substance becomes positively charged which possesses the higher dielectric constant. The term "dielectric constant" in being variously defined also has been described simply as expressing the ease of displacing an electron within an insulator. The potential difference between, or its equivalent, the charge per unit of contact area of any two such substances in contact is proportional to the difference of the two dielectric constants.

The dielectric constant for para rubber, for example, ranges around two to three, depending upon its inherent composition, while for glass it ranges from about four to nine. Because of their high conductivities, metals have long been considered to have dielectric constants of infinitely large values, but more recently their values have been ascribed to an order of three to four as a result of the definite positions which metals take in the contact-potential series that embrace a wide scope, and a large number, of substances. Hence ordinary rubber would acquire negative electrification in contact with most metals or with glass, although for glass, because of its larger value of dielectric constant, the magnitude of the charge would be proportionately greater than for metals.

If two substances of crystalline structure which possess perfectly flat, or so-called optically flat, ground surfaces are placed in contact, their contact electrification, thus acquired, is entirely independent of the physical pressure between them. Since the surfaces of materials which form contact by pairs in industrial processing are relatively rough and uneven, in comparison to optically flat surfaces, their contact electrifications are found to increase with incremental pressures up to a characteristic maximum, or saturation, value for the two substances. This maximum charge is attained when every microscopic unit area of one surface is in complete contact with corresponding unit areas of the other, as would readily obtain, without appreciable pressure, if the two substances formed perfectly flat surface contact. If an amorphous substance, of which rubber is an example, forms a perfectly flat contact with another substance, unlike crystalline materials, the resulting contact electrification increases with pressure until a maximum charge is attained, after which the charge remains independent of additional pressure.

In particular, where one of the substances is fibrous such as a textile, the process of rubbing the substances together causes many more parts to form momentary contacts than would stationary pressure alone, so that in this manner more electrons may pass from one substance to the other and thus augment the charges on each of them. Although this process of electrification by rubbing one substance against the other is often called "frictional electricity," actually the basic process of generation here is still the application of the contact-difference-of-potential theory.

The rubbing of a vulcanite rod with a piece of flannel or fur is an example of this so-called frictional effect in creating electrification. Although the difference of potential between the opposite charges on the two contacting substances may be only a very small fraction of a volt, perhaps of the order of millivolts, yet upon an appreciable separation of the two members, the voltage may increase thousands or even millions of times, thereby causing the ultrahigh potential differences which are so frequently observed in many industrial processes. As is well known, the electrification produced on a vulcanite rod by rubbing it with fur may remain there for hours when the air is dry, even though one end is held in the hand or connected by a wire to ground. If the vulcanite were a perfect insulator, the electric charges could remain impounded on its surface indefinitely, but because no substance is a perfect insulator, the electric charges at one area gradually diffuse over the entire surface of the substance. Under this condition, if a conductive path were provided, the charges would flow to ground.

From this explanation the answer should be clear to the query "is grounding the panacea to all electrostatic problems?" Under certain conditions, grounding will effectively discharge electrified conductors instantly; but obviously, charged insulators are not affected by grounding, except over long periods of time. Other methods of neutralization than grounding must be applied in the case of insulators; unfortunately, it is on substances of this kind, which are the most common types of products in many manufacturing operations, that the most troublesome problems of electrification occur.

HUMIDIFICATION AS A GROUNDING TECHNIQUE

It was mentioned earlier that, provided the ambient air was dry, electric charges generated at one end of a vulcanite rod would remain there for hours even while the other end was grounded. It should be clearly understood that this statement does not imply that, conversely, if the relative humidity is high, the electric charges drain off directly into the humid atmosphere. Moisture in the air in vapor form, as available data substantiate, is much too tenuous to provide this direct means of dissipating the charges, and in fact, water vapor in the atmosphere has been found to be practically a perfect insulator unless the strength of an applied electric field exceeds a certain critical value. Except for a few unusual materials, of which ceresin wax is a notable example, most substances possess hygroscopic properties, by which physical behavior water vapor from humid atmospheres may condense upon surfaces under certain conditions, and in so doing may render them partially conductive.

In this manner, if conditions are favorable, humidification causes more or less imperfect grounding. The surface film of moisture reduces the surface resistivity, while the volumetric resistivity depends upon the degree of absorption of the substance. The conductivity of the moisture is greatly affected by its ion content, and this is affected largely by the solubility of surface impurities or by the surface molecules of the substances, particularly where acid or alkaline solutions are formed. If on the other hand, substances are maintained at a temperature above that at which surface films of moisture can form, because of the processes of evaporation, then the surface cannot become conductive even though the relative humidity be high.

The humidity, when formed by fine spray, as from spray-type humidifiers or from steam jets, can lead to electrification under some conditions rather than to its mitigation. In the spray mists at the foot of water falls, it has been found[1] that below diameters of 80 angstroms, the water particles are always found negatively charged, while for diameters between 80 and 150 angstroms the vapor particles are always positively electrified. For vapor particles larger than 150 angstroms, no electrification is found. (One angstrom equals 10^{-8} centimeter.)

In this connection, the condition should be mentioned that, with hygroscopic materials in the presence of high-humidity atmosphere, even the generation of appreciable electrification is not favored because the two substances behave as conductors, even though both may be nonconductors. In other words, while the two component substances are pressed firmly together or rubbed tightly against each other, positive charges on one and negative charges on the other are actually produced; but in the act of separating the component materials, the charges reunite and leave little or no resultant electrification in evidence.

On the converse, in the absence of practically any surface moisture, such as for values of humidity of the order of one to five per cent, the author has found a marked reduction in the degree of possible electrification. Under this condition, electrons can only pass from one substance to the other at the microscopic high points which form contacts between the two. In the presence of a slight amount of surface moisture, as when humidities of from 10 to 25 per cent are prevalent, the microscopic contacting points may be considered as being broadened into greater areas of contact, as well as the number of contacts being considerably augmented. Both of these conditions favor the passage of more electrons from one substance to the other. Since the amount of moisture on the surfaces in contact is still too small to render them even appreciably conductive, the electrons become entrapped upon one of the substances when separation of the two surfaces occurs. For a given set of physical conditions, an optimum value of electrification may be determined for a given value of relative humidity.

The change in leakage resistivity with humidity for various natural and synthetic waxes and for bakelite[2] is shown in Figure 1, wherein ceresin wax is seen to be notably superior, and in fact almost perfect, as a nonhygroscopic insulator.

If electrification by friction is possible, and the two members are charged as a result of favorable low humidity, grounding of the insulated substance does not result in its immediate discharge. If the other substance is conductive, and its charges are not bound to it by the attractive electric forces from the charges of the insulated member, grounding is effective here in completing its discharge. Actually though, if the separated members are in close proximity, the positive charges on the one do remain bound to the negative charges on the other by virtue of the electric field between them, even though one should be grounded. If both members are grounded, and both are conductors, the opposite charges would then flow together, as a conductive interconnection is provided between them. Should one of these interconnected members be an insulator, the high resistance of it would prevent its electric charges from neutralizing those on the other, except as neutralization would occur by the slow process of gradual leakage of the charges through the imperfect insulation.

Should electric charges be continuously developed and should they be generated more rapidly than they can neutralize each other by the process of leakage, then the voltage between the two generating substances would continue to rise until a certain saturation level is approached. This saturation level of voltage between the charging members is influenced by two electrical properties; one is the gradual decrease of electron flow from one substance to the other through their contacting surfaces because of the increasing repulsion to their flow by the accumulating negative charges on the negative substance; and the other property is that, beyond a definite critical amount, or density, of charge on the two substances, the voltage which is developed between them, as the substances separate, causes the initiation of a "corona" within the intervening atmosphere whereby the otherwise almost perfect insulation of the ambient air is made semiconductive by the production of ions and the charges on the two substances become partly neutralized in this manner.

PROPERTIES OF CAPACITORS

When two charged conductive members are in proximity and insulated from each other, the pair constitutes a capacitor. Capacitors are not always so geometrically formed as one finds them in the laboratory or in a radio set. As an illustration in practice, consider where one member, or plate, may be the ground and the other a metal roof of highly irregular form, which is supported and insulated from ground by a wood-framed structure. The capability of a capacitor to store electricity, called its capacitance, is expressed by either of two basic and well-known definitions: one in terms of the physical factors, $C=KA/t$; and the other in terms of the electrical factors, $C=Q/V$. Another important relationship which is basic to electrostatic problems is obtained by equating these two expressions and solving for the difference of potential, giving $V=Qt/KA$. In these expressions the symbols have the following significance:

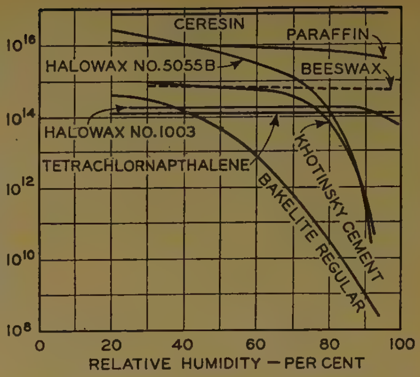

Figure 1. The surface resistivity of certain waxes is seen to be independent of relative humidity, whereas for most of the otherwise excellent insulators, as for bakelite, their resistivities vary greatly throughout the humidity scale

C = capacitance in farads

A = active area in square centimeters, where active area is that area of the dielectric between the plates which is under stress of the electric field

t = thickness in centimeters of the dielectric between the plates

K = dielectric constant

Q = electric charge in coulombs

V = potential difference in volts between the plates

The electric energy which is stored in a capacitor is vitally important in electrostatic problems, as it determines the intensity of the spark and the potentialities for ignition from a spark which occurs between the plates. The expression for the electric energy stored in a capacitor is

Energy $E={}^1/_2CV^2$ joules, or watt-seconds

As an illustration of the application of this sparking energy in fire or explosion hazards from volatile flammables, consider some of the common hydrocarbon fuels which, when admixed in vapor form with air at atmospheric pressure, range within the combustible limits of approximately 1.2 per cent and 8.0 per cent by volume. Some of these can be ignited by an electric spark whose threshold energy is as low as 0.0005 to about 0.001 joule. Characteristic curves[3] are shown in Figure 2 for minimum ignition energies in terms of fuel–air mixtures for benzene and for natural gas under conditions of different sized electrodes and gap lengths. The increase in the threshold values of the ignition energy, as shown here, which results from the cooling effect of larger electrodes at a given gap length for benzene, or of shorter gap lengths for a given electrode size for natural gas, are strikingly illustrated in this figure. The influence of gap length on minimum ignition energy for electrodes of one size—$^1/_2$-inch-sphere electrodes—is illustrated in Figure 3 for natural gas. The threshold ignition energy approaches its minimum value for spark gaps somewhat longer than 0.10 inch, while for spark gaps under 0.05 inch the ignition energy is seen to increase greatly. A person whose capacitance to ground is, say, 100 micromicrofarads, that is, 10^{-10} farad, if charged to 10,000 volts from scuffing on a rug, can provide a spark energy upon discharge of 0.005 joule, or roughly ten times the minimum energy necessary to ignite a flammable mixture of benzene vapor and air.

The plates of a charged capacitor may be connected together by a wire, in which case the plates would be discharged instantly. If, on the other hand, the wire had a resistance R of very high value, the flow of electrons from one plate to the other, which causes the discharge, would be greatly retarded, so that several seconds, minutes, or even hours would be required for completing the discharge. The time in seconds for full discharge to take place is about three times the time constant, where the time constant is equal to the product of the capacitance C in farads of the capacitor and the resistance R in ohms of the discharge path. The expression for the time constant T is

$T=CR$ seconds

and for the time t in seconds for the full discharge of a capacitor, the expression is closely

$t=3CR$ seconds

Inasmuch as the term "time constant" is employed so frequently in considerations relative to electrification, the meaning of the term is clarified still further by showing it graphically on a charge and discharge curve for a capacitor. As Figure 4 shows, a capacitor charges to 63 per cent of its ultimate value during the period of the time constant; and on discharge, it loses 63 per cent of its charge during the same period of the time constant.

As an illustration of the application of the time constant, consider the time required for a tank truck of 1,000 micromicrofarad capacitance to discharge through its tires to a grounded steel grating on a bridge, where the resistance of the wires in parallel to ground is, say, 10^9 ohms. The time constant $T=1{,}000\times 10^{-12}\times 10^9=1$ second, and the time for complete discharge is closely $t=3T=3$ seconds. If the charged truck came to a stop on a dry concrete highway, where the resistance from the tires to ground through the concrete is, say, 10^{12} ohms, the time for complete discharge would be 1,000 times greater, or 50 minutes.

If a piece of fabric in a processing machine of some kind is electrified, by reason of its charge it constitutes the equivalent of one plate of a capacitor and the ground, most probably, being the other plate. If a wire connects one point on the charged fabric with ground, the time of discharge, here too, depends upon the time constant of the discharge circuit. In this instance, because of the varying lengths of flow paths to the wire, the resistance varies widely for the flow of the charges through the high resistance of the fabric.

GROUNDING FROM NATURE'S STATIC—LIGHTNING

A charged cloud, say of negative electrification, is known to form strong electrostatic attraction with equal numbers of positive charges in every intervening structure on the earth's surface below, be it a steel-framed building or tower, or a tree, or a rubber-tired tank truck. These positive charges have been formed by the process of electrostatic induction from the cloud, whereby the negative charges of the cloud repel electrons from atoms or molecular groups in those structures within the influence of the intervening electric field. As the electrons evacuate their neutralizing positions in the atoms and molecules, positively charged ions remain which are bound electrostatically to an equal number of negative ions in the cloud. If electrification of the cloud increases, other factors remaining constant, the increasing voltage between the cloud and earth may cause the ionizing potential gradient of the air to be exceeded wherever sharp edges and points exist and thereby greatly multiply the number of air-borne ions. Since these ions cause a neutralization of some of the positive and negative charges at the earth's structures and the cloud, and thus reduce the voltage between the cloud and earth, the probability of a lightning stroke is appreciably lowered.

This corona effect is the principle upon which the use of the lightning rod is predicated. By employing sharp-pronged aerial terminals on lightning rods which project well above the structure to be protected, the density of the charge at the sharp tips, or in other words the electrostatic field intensity or the voltage gradient, is enormously increased. In this manner, the critical voltage gradient causing corona discharge is reached at the sharp points at a much lower cloud-to-earth voltage than would otherwise occur. Hence, the striking voltage may be held somewhat in check, tending to diminish the likelihood of a direct lightning stroke; but in the event of a stroke actually occurring, it is more apt to impinge upon the lightning rods than elsewhere, because the conductive ionized paths in the air, along which the stroke travels, emanate from the "corona points" on the rods. If the lightning rods, their interconnecting leads to ground, and the grounding electrodes are all properly installed, the lightning stroke passes harmlessly through the conductors into ground, or vice versa.

If the ground resistance is high, say 100 ohms, then as little as 10,000 amperes through it would cause a potential difference across it of 1,000,000 volts. This high voltage could very well lead to side flashes through part of a building or elsewhere from which attendant hazards or damage could result. The current in some lightning strokes is well over 100,000 amperes, and the need for low-resistance grounds is even the more apparent. In other words, terminal ground resistance for lightning protectors should be maintained as low as feasible, of the order of one ohm or less if possible, and the grounding plates, where used, should be buried to a depth of at least ten feet. By so doing, the paths of flow of current from the buried electrode into the surrounding earth are so deep that the probability of dangerous potential gradients existing on the surface of the ground above is much less than for a shallow buried electrode. Voltage gradients at the surface of the ground, which are produced in this manner, account largely for the frequent electrocutions of cattle from direct lightning strokes to trees, as they gather under trees for protection from storms.

If the rate at which the charges are generated on the cloud exceeds the rate of the neutralization of charges by the discharging process of corona, eventually such a high voltage is attained that the intervening air between the cloud and earth becomes sufficiently conductive along ionized streamer routes to permit the initiation of a mighty spark—a lightning stroke—which in a few millionths of a second discharges the cloud, or a certain portion of it. At the earth's surface the lightning stroke generally impinges upon the tallest conductive structure which is beneath it, such as a tall steel building; but the current in the stroke, which may be many thousands of amperes, causes no harm provided the electrical resistance at the foundations of the building to ground is negligibly small. Such a tall conductive structure normally provides a "cone of protection" against lightning strokes to nearby structures of lesser heights, if the latter are contained well within the bounding surface of an imaginary cone as formed from the apex of the tall building to a symmetrically centered base at the ground plane which has a circle roughly equal in radius to at least twice the height of the building.

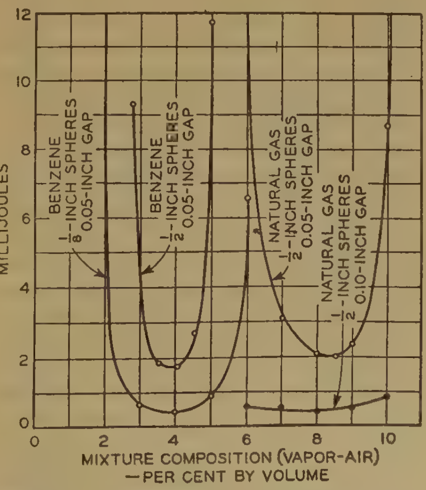

Figure 2. Minimum electrostatic ignition energies for benzene and natural gas are shown as functions of fuel-air mixture, electrode size, and spark-gap length

Predicated on this hypothesis, the lightning protection of critical areas has been provided by the erection of one or more tall steel towers on properties which house munitions manufacture and storage, large oil reservoirs, gasoline tank farms, and other locations where costly damages could result from fires and explosions if they were permitted to be initiated by uncontrolled lightning strokes. Where a number of towers are erected for this purpose, more effective protection is afforded by the stringing of barbed wires from top to top of the structures. In all such grounded structures, charges of opposite polarity to those on the overhead cloud are induced and they are held there bound only so long as the overhead cloud remains charged. If a cloud-to-cloud lightning stroke discharges the cloud, the charges on the structures are no longer bound, and they neutralize themselves harmlessly by combining with the opposite charges from the earth.

A cause for many "mysterious" fires, however, has arisen from a somewhat different condition wherein an insulated conductive member, forming a plate of a capacitor, such as an ungrounded metal roof supported on a wood structure or a tank truck standing in a concrete-paved loading yard, becomes charged from a passing cloud by electrostatic induction over a very considerable period of time. Because of the imperfect high-resistance insulation intermediate between such structures and the ground, electric charges are induced slowly into these partially insulated members, slowly because of their large time constants. If the inducing cloud floats away or becomes suddenly discharged, the charges of opposite polarity which were slowly induced upon the structure are no longer electrostatically bound, and thus they remain impounded there as a result of the high resistance to ground. Now a high voltage exists between the electrified structure and ground which is an unsuspected but potential source of fire hazard. All that is needed to initiate a fire or explosion, resulting from such a charged structure, is the synchronized occurrence of a flammable mixture of fuel vapor and air and a spark of sufficient energy to cause its ignition.

Here is an instance where grounding, if applied to these otherwise insulated structures, would eliminate these potential fire hazards. In other words, in localities where flammable fuel–air mixtures may cause hazardous atmospheres, extra precautions should be taken to insure thorough bonding and grounding of all isolated metal parts of structures and of large metal surfaces throughout the dangerous zone.

CHARGING OF INDIVIDUALS

The experience of discharging long sparks from one's finger tips to a radiator, gas stove, or elevator after walking on carpets or rugs within doors during the cold, dry, winter weather is frequently amusing, but the experience, if permitted under certain other conditions, may be surcharged with grave consequences. Explosions have originated in this manner in hospital operating and treatment rooms from anesthetic vapor and air mixtures which have resulted in serious injuries or deaths to patients, to surgeons, and to attendants, as well as in demolition of buildings. Certain industrial processes in ordnance plants, for example, are so susceptible to explosion hazards from body electrification as to make necessary the exclusion from employment of certain individuals whose abnormally dry skin is found, by test, to cause them to retain electric charges more persistently than others. This physiological condition of dry skin can be corrected by administering certain types of diet and proper vitamins.

An instance is known to the author where a person became so electrified by walking a short distance upon a dry concrete driveway during a cold dry fall day as to have caused the ignition of the hydrogen gas escaping from the storage battery of his recently parked automobile following his removal of the fill caps preliminary to refilling the cells with distilled water. This explosion caused serious injury to his eyes—the loss of sight in one eye, and only by repeated operations was the sight restored to the other eye.

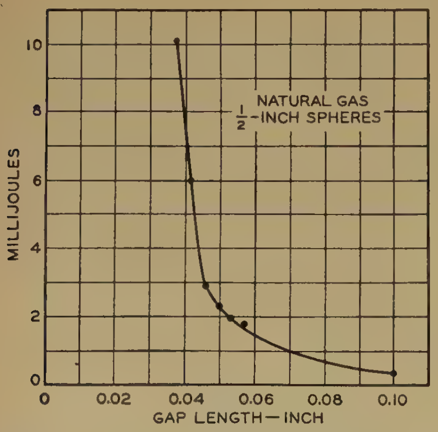

Figure 3. The variation of minimum ignition energy with spark-gap length is seen to be highly critical for short gaps and practically constant for the relatively longer gaps

The accumulation of electric charges on a person's body is affected materially by the high-resistance characteristics of the shoes and socks which he wears and of the surfaces upon which he walks. Carpets and rugs, with their deep nap, are particularly conducive to the generation of high electrification. To a lesser extent than woolen floor coverings, but still seriously offending sources are linoleum or rubber floor coverings, granolithic and concrete floors, synthetic floor compounds, such as plasticized compositions, waxed surfaces, and certain types of floor paints, especially those employing a titanium-oxide base. Of footgear, the worst offenders are shoes possessing crepe-rubber soles, natural-, reclaimed-, or synthetic-rubber soles, rubber inner soles, or leather sole construction employing liberal amounts of cement or glue compounds, or rubber overshoes or rubber boots.

By way of illustrating the effect of the resistance of footwear, assume the resistance to ground through both shoes to be 1,000 megohms, or 10^9 ohms, and assume the person's capacitance to ground to be 100 micromicrofarads, or 10^{-10} farad, then the time constant, being the product of the two quantities, is 0.1 second. If the resistance of his shoes to ground were ten times higher, or 10,000 megohms, the time constant would, even then, be only 1.0 second. Hence a person would ordinarily discharge quickly to ground if, in his walking, he should tread on well grounded flooring, provided he does not wear rubber footgear. While they are dry, even silk or woolen hosiery can provide the same high-resistance effects as rubber soles.

When operators must work in zones where flammable substances or volatile liquids and explosive vapors are manufactured or used, utmost precautions must be constantly observed in order to insure proper grounding of individuals. Either the entire floor should be of grounded conductive construction, or if this is considered unnecessary, where machines are employed in unit operations, grounding foot plates and grounding handrails should be so artfully installed that the operators, in approaching the danger zones, cannot avoid treading upon the plates and touching the handrails. Various types of conductive floor coverings are available which, by grounding, can discharge any electrification imparted to them.

A number of manufacturers are producing conductive shoes, and although they may not possess really low resistances from body to ground, it is not generally necessary that they should. This can be demonstrated by the following example. In walking rapidly at the rate of four miles per hour, a person takes about two steps per second. Hence, if his electric time constant is of the order of 0.1 second, corresponding to 1,000 megohms for the resistance of his footgear to ground and a capacitance of 100 micromicrofarads, his body would fully discharge during each step. In other words, under these conditions the person could accumulate no appreciable charge.

The greatest offenders in creating "unfriendly" sparks in hazardous zones are visiting executives and employees from other departments of the plant. These visitors are not as well trained to safety consciousness as those who regularly work in the dangerous locations and as those who, perhaps, have seen a fellow worker injured or killed from the result of a momentary relaxation of a safety measure.

POWER AND CONVEYOR BELTS

The annual cost of fire and explosion losses in the industries of the United States caused by electrostatic ignition from power and conveyor belts is estimated at about $4,000,000. These losses occur throughout a wide variety of industries, such as in those using belts to drive machinery in locations where flammable vapor–air mixtures are a potential fire hazard, and in those where power and conveyor belts are utilized in cereal, sugar, starch, and flour mills, in grain elevators and threshing machines, and in sulphur and other dispersion processing. In these industries the dusts constitute finely dispersed fuels of a highly explosive nature, requiring only a properly timed spark and dust–air mixture to cause a catastrophe.

Sparks of four-foot length, estimated in the order of 1,000,000 volts, have been observed occasionally from wide high-speed power belts under favorable conditions. Elihu Thompson reported such observations. Spark discharges from belts ranging from 60,000 to 100,000 volts are more commonly encountered in industrial plants. The charges which are generated on the surface of the belt as it makes tight contact with the pulley face are trapped there by the high resistance of the belt as it separates from the pulley. Each electrified unit area of the belt as it leaves the pulley, because of its capacitor effect, develops a high voltage which attains its maximum value some four or five inches after its separation from the pulley. The slipping of belts has been found to have little, if any, effect in augmenting the electric charge generated by its normal operation. Pulleys should possess conductive properties, as otherwise considerably higher voltages can be generated on the belts.

The pulley and its associated machine rotor should be meticulously grounded in order to permit the continuous electric discharge of the rotating system. If this provision is not made, then the oil films f the bearings virtually insulate the rotor rom the grounded frame of the machine, nd depending upon the purity of the ubricating oil, the voltage of the rotor bove ground may attain values of 3,000 o 5,000 volts, or higher. In case the belted nachine should be a dynamo, the insulaion on the rotor windings may become rematurely weakened to the rupturing oint by the continual attack upon it of he corona effect of the spurious electrostatic ield. The grounding of the rotor may be chieved by mounting a grounded brush irmly against the shaft.

The primary hazard of the electrificaion of the belt really lies in the magnitude f the stored charge and in its consequent igh voltage, and because of this, in its otentiality for sparking. If the belt was omposed of conductive material, then no appreciable voltage would result in its peration with a conductive pulley, as each unit area of the belt would continuously and harmlessly discharge at the instant of its separation from the pulley. Just prior to the outbreak of the war, conductive belting was beginning to make its appearance on the market. The use of such belting in conjunction with conductive pulleys constitutes an ideal solution to electrostatic problems of this particular nature.

If the belt is nonconductive, as it generally is, the electric charges may be dissipated by treating the belt with special dressings to provide hygroscopic and otherwise conductive surfaces. Most of these dressings which employ the use of fish oils, glycerine, carbon black, and other hygroscopic or conductive elements require replacement every week or two, and hence the maintenance expense is appreciable. Engineers of the United States Department of Agriculture have developed belt dressings for rubber and leather belts which last for six months or more per application and have been found quite satisfactory.

THE PAPER AND TEXTILE INDUSTRIES

Aside from such special processes as the carding of staples and the production of yarns and threads in the textile field, a number of the processes in the manufacture of paper and textiles have similar problems of electrification. In fact some of these problems are akin to those of power and conveyor belts. The similarity with belt operation is apparent where the paper or textiles flow continuously, frequently at high speeds, unwinding from one roll and rewinding on another, traveling over idler rolls, through driers of various types, through printing machines, and perhaps into cutters. Both paper and textiles are more susceptible to electrification in running over and through systems of rollers than are either rubber or leather belts. There are two basic reasons for this:

1. The resistivities of paper and textiles are, n general, considerably higher than belting so that they retain their charges in greater proportions.
2. Unit areas of the porous paper and cloth fabrics permit much of their inner structures to press and twist into contact with the processing rolls and thus to become charged to greater density by friction effect than would be true if they had a firm, hard structure like that of belting.

Just as for belting, the paper and textiles, as they leave the rollers from which they are charged by contact difference of potential, develop high voltages to ground. But unlike belting, the paper or textile stocks obviously cannot be made conductive by applications of dressings in order to ground the static charges. The presence of high-voltage electrification creates a variety of annoying and hazardous conditions. Machine operators are always confronted with the specter of gruesome personal injuries from being caught in gearing, rollers, belting, and rotating machines resulting from sudden uncontrolled movements which are caused by surprise shocks from the high static voltage. Women operators, by relaxing safety regulations, have suffered most serious accidents by having their electrified hair drawn into gearing, belting, or processing equipment.

In some instances, sparks have defaced high-quality paper, or caused fires by igniting fine lint which gathers on and around certain textile equipment. Where printing of paper or textiles is in progress, fire and explosion hazards are always present as a result of the flammable nature of the volatile solvents in the printing ink. This condition is particularly aggravated in the case of multicolored printing in which the inks possess especially volatile solvents for quick drying in high-speed printing, as in rotogravure service, and in wallpaper and wall-cloth manufacture. As a result of electrification some operations are slowed down appreciably, while others are caused to stop repeatedly because of clogging of machines by the stock. This occurs especially in the folding and stacking of paper, ginning of cotton, and carding of staples. Voltages are especially high on paper and textile fabrics in those operations where high pressures are exerted between processing rolls, such as in calendering and embossing of paper or in calendering processed cloth, and because of this, the hazards of electrification are intensified and multiplied.

The rolls, cutters, printers, and various metal parts of the manufacturing and processing machines for both paper and textiles can, and should be, grounded thoroughly, using grounding brushes on rotating shafts of rollers, idlers, and parts which may otherwise be insulated from machine frames by the oil films within the bearings. Obviously the grounding does not eliminate the static charges, as these are entrapped on the high-resistance paper or cloth fabrics, but grounding does keep the machine parts at ground potential, and hence it controls the magnitude of the voltage to ground by not permitting an accumulative voltage rise.

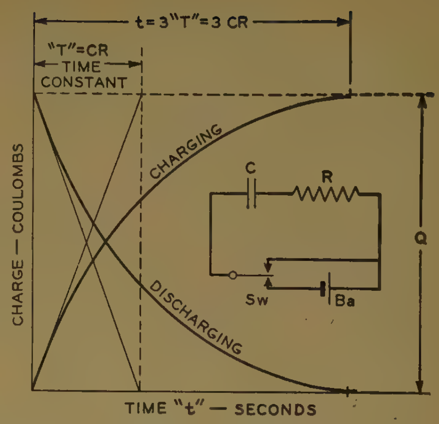

Figure 4. The time constant for the electric circuit shown depends upon the values of *C* and *R*, and it is the same for either charging or discharging

In those operations where sparking constituted hazards to safe operation, the electrification of the moving paper and textiles sometimes has been discharged by providing tinsel bars at strategic locations across the width of the moving paper. Here the strings of tinsel were supported by a grounded bar; and, by lightly touching the stock, they were supposed partially to discharge it. Or in place of this method, the stock may be lightly touched by dangling pieces of fine chain which are attached to and supported by a grounded metallic bar. These and other such methods have been employed to a limited degree in the paper and textile industries for decades, despite the added maintenance costs that are necessitated by their upkeep and replacement. The electrostatic problems in modernized paper and textile operations have been aggravated and intensified by the higher electrification resulting from the increased speeds of manufacture, of printing, and of the many attendant processes.

Where fire or explosion hazards, as from the vapor–air mixtures of flammable liquids or gases, are not present, the electrification of belts, paper, and textiles can sometimes be economically and satisfactorily reduced to safe values by the use of static combs. A static comb is placed close to and across the path of the moving stock. It is constructed with an insulating member secured to the supporting ground rod, and the insulating guard is so provided with holes that the corona points projecting from the ground rod lie centered within the holes and the corona points are depressed below the exposed surface of the insulating guard so that the points cannot touch or mar the surface of the stock. Static combs can reduce the voltage to about 10,000 volts, and with modified construction to considerably lower values. This order of voltage, under gas-free or explosive-vapor-free conditions, is not hazardous. The author has used this method to advantage in the economic solutions of certain types of electrostatic problems. Like doctors' prescriptions, though, these devices cannot be used indiscriminately in the control of electrification without, on occasions, leading to serious consequences.

Localized humidification, by means of wet steam directed by jets onto the moving stock, is used in some processes as an agent for dissipating the charges to ground. Only certain processes lend themselves to this method since the humidified surfaces, thus provided, may acquire undesirable properties which may influence subsequent operations or the quality of the finished product. The steam should be critically controlled, when this method is employed, so as to avoid overhumidification or the dripping of steam condensate. On the other hand, dry, rather than wet, steam independently may contribute, under some conditions, its own generation of electrification. Humidification has been employed extensively over many years in certain processes of the textile industry for the control of static electricity, and to a lesser extent it has been used in the paper industry.

In the cotton industry, static electricity has been a troublesome factor from the beginning of the machine processing. In carding and drawing operations, for example, static electricity causes fibers to fly apart and, hence, to weaken the yarn. An illustration of the electric repulsion of fibers in yarn is shown in Figure 5. Exposure of the fibers to a 50 per cent to 55 per cent relative humidity during these processes has been found to control the electrification fairly well, but if the humidity is increased a few per cent higher, the cotton may then clog on the carding units. Under these conditions, the cotton sometimes catches on fire because of intense frictional heating.

The addition of moisture to the cotton yarns to the extent of eight per cent is stated to increase the tensile strength 30 per cent above what it would be at four per cent moisture. This moisture conditioning of the yarn is believed to improve the subsequent operations of cotton spinning and weaving. The effect of a change in relative humidity from 44 per cent to 82 per cent was found to increase the tensile strength[4] of cotton fabric 14 per cent and linen fabric 21.3 per cent, and to decrease the tensile strength of woolen fabric 14 per cent. Humidities may be maintained in cotton spinning rooms around 55 per cent to 60 per cent while in cotton weaving 80 per cent to 85 per cent are sometimes employed. In general, throughout the cotton industry, the range of 50 per cent to 55 per cent relative humidity is considered beneficial, chiefly so as a means of providing a regain of moisture to the cotton fiber for increasing its strength during processing. Coincidentally, humidification of this range, if properly applied, seems also to provide an adequate lowering of electric resistance within the product for the grounding of electric charges.

PETROLEUM INDUSTRY

The flow of hydrocarbon liquids, as well as other flammable and volatile fluids, through pipe and hose lines may develop very considerable volumetric electrification[5] by the principle of contact difference of potential. Since the resistivities of hydrocarbon liquids are very high, ranging from 10^{10} to 10^{18} ohms per cubic centimeter, the electric charges do not move readily through the fluid under their own interelectrical forces. Strangely enough, too, these fluids do not readily electrify when pure, but the presence of small amounts of impurities, such as free or combined water, tetraethyl lead, entrained air, or metallic oxides is found to accentuate the generation of electric charges. Measurements have shown that the generation of electricity in the flow of gasoline through pipe lines and conventional fill hoses increases about linearly with the rate of flow. On the average, this rate of flow of the electric charges in gasoline has been found to be approximately 3×10^{-10} ampere per gallon per minute.

If gasoline, in flowing through a pipe line at the rate of 100 gallons per minute, discharges into an insulated tank for a period of five minutes, the quantity of electricity stored in the tank at the end of five minutes is

$$\text{Quantity } Q=3\times10^{-10}\times100\times5\times60=9\times10^{-6}\text{ coulomb}$$

Assume the insulated gasoline tank has a capacitance of 450 micromicrofarads, that is, 4.5×10^{-10} farad, then the voltage developed between the tank and ground is

$$V=\frac{Q\text{ (coulomb)}}{C\text{ (farad)}}=\frac{9\times10^{-6}}{4.5\times10^{-10}}=2\times10^{4}=20{,}000\text{ volts}$$

Should this high voltage cause a spark to jump between tank and ground, the energy in the spark would be

$$E={}^1/_2CV^2={}^1/_2\times4.5\times10^{-10}\times(2\times10^4)^2=2.25\times10^{-10}\times4\times10^8=90\times10^{-3}\text{ joule}$$

This spark energy is seen to be 90 times the conservative threshold energy of about 10^{-3} joule as required to ignite a flammable mixture of gasoline vapor and air.

If the tank in the foregoing example had been grounded, as all storage tanks always should be, the charges in the liquid for a small tank could not accumulate and thus they could not develop the high voltage as shown. On the converse, if the pipe line in this illustration which supplied gasoline to the tank had been insulated, an equal quantity of electricity, but of opposite polarity, would have accumulated on it. Obviously, pipe lines also should be grounded thoroughly.

Hose lines have so-called static wires enmeshed in the rubber which bond their brass connectors at each end and thus a tank truck is presumed to be grounded when the hose is connected to it, provided the discharge end of the hose is grounded by contact with the fill pipe of the storage tank. In cases of ordinary loose nozzles being placed in fill pipes, this may not be true, and hence a serious ignition hazard can exist at the opening of the fill pipe where flammable vapor–air mixtures are most likely to be present. The screw-in discharge nozzle, of the type required in the City of New York,[6] assures reliable grounding of the truck to the tank and also precludes the escape of explosive vapor–air mixtures at the fill pipe. A tank truck should be electrically discharged before its hose connections are made by attaching a permanently connected reel-in grounding cable from the truck to a suitable grounding clip on the vent pipe or other part of the storage tank.

The rain discharge of petroleum, and other flammable products, from an overhead orifice into a tank aggravates the problem of electrification and of fire hazards. The breaking up into drops of the inflow stream of the product between the end of the discharge orifice and the surface of the liquid in a tank, especially in large field storage tanks, may be, in some instances, a further source of electrification—a phenomenon akin to that by which clouds become electrified through the breaking apart of water droplets. Sparks as much as four feet in length have been reported as occurring from the surface of oil to the sides of the tank where cylinder oil was being discharged from an overhead orifice into a large steel storage tank.

The petroleum or other products should be introduced into the storage tank near the bottom, using discharge fittings so arranged at the side of the tank as to direct the electrified fluid against the grounded metal. Violent agitation of the liquid within storage tanks should be avoided, especially where it disturbs the water bottoms in the tanks or where it allows air to discharge up through the liquid, as these conditions may also generate hazardous

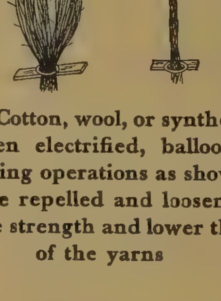

Figure 5. Cotton, wool, or synthetic staple yarns, when electrified, balloon during their spinning operations as shown on the left, and the repelled and loosened fibers weaken the strength and lower the quality of the yarns

lectrification. This difficulty is unavoid- bly encountered in tank agitators for the urification of kerosene and other petro- eum products at refineries; and unless pecial methods of mitigation of electri- ication are applied here, fire and explosion azards are constant threats to plant afety.

Field storage tanks of a wide variety of onstructions which range in sizes up to 50 feet in diameter are found in service. Experience seems to indicate that the all- teel type of tank, with floating roof tructure, is particularly free from hazards f fire and explosion possibilities. With his type of roof structure, little or no gas torage space is provided above the prod- ct. Obviously too much attention can- ot be directed toward providing and aintaining tight valves, leakproof fittings nd manholes, and properly installed acuum-pressure vent systems. Steel anks constitute their own safe lightning rotection, just so long as no gas leaks are ermitted and adequate ground conduc- ion is provided. Wood-roof tanks and eservoirs have the least degree of safety rom lightning hazards.

Throughout the petroleum and other ndustries in which highly flammable vola- ile products are manufactured, trans- orted, and utilized, fire and explosion azards abound on all sides. Generally peaking, these electrostatic hazards are ecognized only vaguely by the operators ithin these industries, but in order to revent fires and explosions, the instruc- ion of operating personnel in safety meth- ds must be given constant attention. This s particularly so whenever any deviations rom standard procedures of handling the roducts become necessary, either as tem- orary expedients or as permanent prac- ices.

RUBBER-TIRED VEHICLES

This subject has been presented by the uthor in a number of periodicals,[7] and ence, only the importance of grounding ill be treated here. In transit on the high- ays, at high speeds, tank trucks may evelop 15,000 to 25,000 volts, or more, to round during favorable weather for electri- ication. Also, in discharging loads of flam- able products, several thousand volts ay be developed. For this reason, ut- ost care should be exercised for the safe andling of all flammable, volatile, prod- cts.

The tank trucks should be promptly rounded upon arriving at their destina- ion, that is, at the loading racks of bulk upply stations, and at service stations. hey should be maintained at ground po- ential during all of their immobile periods n order to avoid hazardous electrifica- ions by extraneous electric induction. In eing parked on concrete and other ultra- igh-resistance pavements, for which the harging time constant may be large, the lectrification of a tank truck to high volt- ge by induction may occur very slowly; but also because of this large time constant, the vehicle when so electrified may retain its unbound charge for an equally long period of time. In the interim, the vehicle presents unsuspected electrostatic hazards which may lead to a fire or an explosion. An example was cited earlier in the article to emphasize this hazard.

Table I. Record of Dust Explosions in the United States[*]

To September 1, 1942

Classification	Total Explosions	Explosions With Injury or Fatality	Number Killed	Number Injured	Number Explosions With Reported Losses	Amount of Losses
Grain elevators	150	59	115	281	138	$24,531,218
Woodworking plants	100	42	30	132	73	2,713,613
Feed and cereal mills	90	37	63	222	79	7,351,510
Flour mills	87	25	28	46	62	4,548,300
Starch and corn products	38	18	128	130	32	5,384,826
Cork dust	37	7	6	28	34	181,190
Pulverized coal	26	14	21	26	24	92,359
Sugar refineries	25	4	12	31	14	1,622,300
Fertilizer plants	26	5	7	20	14	852,450
Malt houses	23	2	2	18	18	747,500
Metal dusts	36	21	49	76	32	1,684,165
Sulphur dusts	23	7	2	39	15	80,095
Bark dust	14	1	0	2	13	587,600
Coffee and spice dusts	11	2	5	13	9	201,700
Cotton mills	13	4	2	4	8	78,950
Paper dust	7	0	0	0	7	395,000
Phonograph-record dust	6	1	0	1	5	36,400
Pitch and resin dust	15	7	14	57	12	2,098,472
Rubber dust	7	3	11	2	6	30,300
Miscellaneous	46	20	24	78	38	2,510,992
Totals	780	279	519	1,206	633	$55,728,940

[*] National Fire Codes for the prevention of dust explosions—1943, National Fire Protection Association.

The perennial question as to the effectiveness of drag chains for discharging rubber-tired vehicles has been settled experimentally by the author, to his own satisfaction, as having no practical value; and, in fact, in some instances, drag chains have been known to introduce additional hazards by virtue of the mechanical sparks which they create. If perchance the drag chain could discharge the vehicle, because of a low-resistance roadway, then the truck body would readily discharge itself anyway through its tires, upon stopping, in the short period of two or three seconds.

Also, attention should be called to a fallacy, which unfortunately is receiving considerable publicity, to the effect that the use of conductive rubber tires would constitute the perfect solution to this problem of electrification of rubber-tired vehicles. If the electric resistance of the highway from the tire treads to ground were of a relatively low order, this statement would be quite true; but in this instance the statement also would hold true even with the use of conventional tires. The fallacy in the statement lies largely in the misconceived value of the electric resistance of the highways. A dry concrete or asphalt highway has a surface resistance and resistance to ground which may be several orders higher[8] than the resistance of the conventional rubber tire from wheel rim to the tread. For this reason the highway would retain its generated electric charges which are produced at the tire treads, and the conductive rubber tires would retain theirs of opposite kind because they could not escape.

In this connection, though, it should be pointed out that, by employing the proper mixture of ingredients in the manufacture of rubber for tires, it may be entirely possible to compound the rubber composition so as to give a low contact difference of potential between the tire treads and the concrete of the highway. If this refinement in tire construction were made, little if any voltage would be developed on the car body while the vehicle was operating on that particular type of concrete highway. However, contamination of dirt on the surface of the concrete roadway, or changes in the ingredients or mixture of the concrete from place to place, would largely counteract the advantage of the special tire composition. Then, too, a tire which was compounded to provide negligible contact voltage with concrete might generate an exceptionally high voltage with asphalt, brick, macadam, or other common forms of roadway surfaces.

DISPERSION INDUSTRIES—EXPLOSIVE DUSTS

In those industrial processes devoted to reducing a vast variety of substances to powdered or granulated form, many of these powders become highly electrified and some are violently explosive. In order to convey some conception of the seriousness of dust explosions in the United States, data from the National Fire Protection Association are presented as Table I.

In addition to the statistical information in this table, it serves to list by industries the origin of many of the dusts that are sources of particular hazards. Only a small proportion of the explosions which have been recorded in the table was allocated definitely to electrostatic origin, although many of those reported as "cause unknown" might well have been from this source. Of all the explosions listed, those occurring in grain elevators are seen to lead in number and in amount of loss, although woodworking plants, feed and cereal mills, flour mills, starch and corn products, sugar refineries, and metal dusts are also serious offenders.

Electrification in many of these industries occurs by crushing, pulverizing, and grinding processes. The products are commonly conveyed from process to process and to storage by conveyor belts, by belt-type bucket elevators, by screw conveyors, by revolving metal screens, or through airblown channels. Their collection for temporary storage is commonly accomplished by dumping into bins through chutes, or by using cyclone, bag, or screen-cloth collectors. All of these methods are conducive to generating extraordinarily high electrification. All metal parts within the danger zone of the plant should be thoroughly bonded and grounded, belts should be made conductive, buckets attached to belts should be interbonded, and bag or screen-cloth collectors should be interwoven with copper wires and grounded. Compressed air never should be used for cleaning by the method of blowing dust about, as in this way the dust may attain its maximum electrification, and some dust clouds, notably sugar dust, may self-ignite from the miniature lightning flashes thus produced within them. Vacuum cleaning is the safest procedure, and meticulous housekeeping throughout the danger zone is of paramount importance.

Humidification, as a mitigating agency for electrification in many of these dispersion processes, may not be permitted because of the deleterious effects upon hygroscopic powders and upon various moisture-susceptible products under manufacture. If humidity control can be applied without harm to the products, it may be as helpful here, depending upon conditions, as in other industries. The introduction of certain highly flammable dry powders into mixers, or the processing of powders in grinders, in attrition mills, or in ball, roll, or hammer mills, may constitute a very hazardous operation. Grounding of all metal parts is essential; but, in addition, other means or modifications in processing may be necessary to control effectively the electrification.

While conducting investigations relative to fire and explosion hazards from electrostatic causes in certain industries, the author has experienced several occasions during which his quantitative findings have lead either

1. To the recommended introduction of more desirable alternate plant processes by which the resulting electrification was reduced to nil.

or

2. To basic changes in certain plant operations whereby substantial annual economies were realized—in addition to providing entirely satisfactory solutions to the electrostatic problems.

GASES AND VAPORS

Gases and vapors, when not contaminated with impurities of foreign solid or liquid particles, have been found to generate little, if any, electrification in their flow. Generally, such a pure condition of gases does not exist, because metallic oxides from the scale of pipes through which the gases flow, or water vapor, or other such contaminants, are commonly present.

Steam in flowing from a nozzle or from a leaky pipe creates particularly high electrification. For example, steam at a pressure of 75 pounds per square inch issuing from a $^1/_{16}$-inch hole and impinging upon a parked tank truck a few feet away was found to develop a voltage of 20,000 volts between the tank and ground in five seconds. This corresponds to an approximate rate of flow of electricity of four microamperes. The grounding of pipe lines and of miscellaneous metallic parts, where fire or explosion hazards are possible, should be carefully performed and thereafter maintained. If the tank truck in the above illustration had been grounded, no electric charges could have accumulated on it.

Compressed air, like steam, also can impart high electrification, when it impinges upon insulated objects. The air, under high pressure, contains particles of condensed water vapor which adds materially to the magnitude of the electrification that is generated. The nozzle or orifice, if insulated, acquires electric charges of one kind, while the projected particles and the air stream possess charges of the opposite kind.

Hydrogen is probably the most hazardous of all gases, as its explosive range with air extends from 4.1 to 74 per cent by volume, and also it is susceptible of ignition by a spark energy of as little as 2×10^{-5} joule. In the pure state, no electric charges are generated by the flow of hydrogen. But as it is commercially handled in industry, such as flowing through pipe lines, discharging through valves at filling racks into pressure containers, or flowing out of containers through nozzles, the hydrogen is found to contain particles of oxides carried off from the inside of the pipes or containers. In this contaminated state, it is highly susceptible to electrification and it constitutes a most dangerous product, requiring utmost care and constant vigilance for safe handling in its manufacture, transportation, and use. If by faulty generation, some oxygen is contained with the hydrogen in the tanks, a violently explosive condition exists. The author investigated an explosion from just such a cause which demolished the service building, damaged others, and resulted in injuries and deaths to workmen.

The spraying of paints and lacquers by aspirating and atomizing them with high-pressure air may generate electrification of dangerous magnitude under certain conditions. The solvents in fast-drying lacquers are highly volatile and flammable, and explosions may be caused from electrostatic sparks where spraying is conducted under improper conditions. Thorough ventilation should be provided and all metal objects within the room should be grounded, and especially the objects being sprayed. Obviously no smoking or flames of any type should be permitted within the danger zone.

Carbon dioxide in being discharged from orifices under high pressure, for industrial purposes, can cause high electrification of the containers. The condition here is not unlike the effects from contaminated compressed air or from steam flow, although the change in state, in addition to the contact effects at the orifice, is believed to play a contributory part in the process of electrification.

HOSPITAL AND TREATMENT ROOMS

Unfortunately, the anesthetics which are applied to patients in hospital operating rooms and in certain treatment rooms are basically highly explosive. Utmost precautions should be demanded by the administrators of hospitals and especially observed by anesthetists. The inane argument has been advanced that the casualty of some 25 patients per year in a rough approximation of 1,000,000 anesthetized admissions to hospitals per year in the United States is too small for alarm. But this argument cannot condone the abuse of the Hypocratic oath of the medical profession in failing to observe

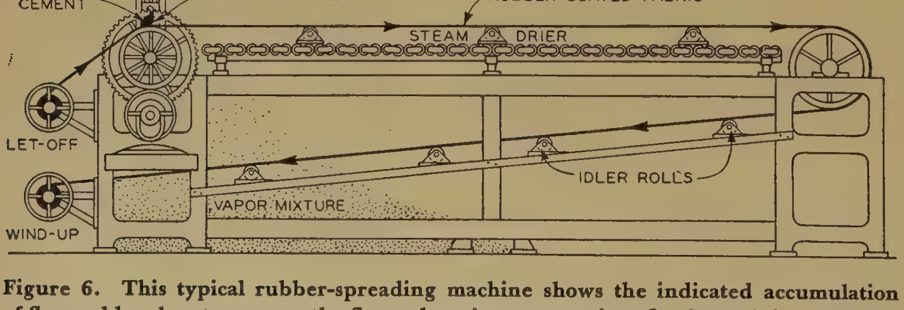

Figure 6. This typical rubber-spreading machine shows the indicated accumulation of flammable solvent vapor on the floor where it creates serious fire hazards in proximity to the dried and highly electrified coated fabric in its return passage over the idler rolls to the windup reel

very possible and known means of preerving human life. Surgeons, doctors, nd operating personnel should be eduated to understand fully the hazards to ife in using the highly volatile and violently xplosive anesthetics which are entrusted o their administrations.

Methods have been devised whereby the pplication of anesthetic vapors can be conined wholly to the patient by the total-ebreathing technique. These methods of otal-rebreathing techniques should be leveloped to the eventual exclusion of the lder methods. Utmost care, even in he approved techniques, must be oberved constantly in order to insure against he production of hazardous electrostatic parks by the flow of the gases through the ontrolling orifices.

In operating rooms, the sources of elecrostatic sparks arise chiefly from the manipulations of the operating-room atendants. Scuffing over and walking upon nsulated floor coverings during favorable veather for electrification generate high voltages on the bodies of the surgeons and he attending personnel. The slipping of ubberized and conventional sheeting rom operating tables is especially conlucive to generating electric sparks. Also, he friction of clothing of nurses may cause langerous sparks. All of these conditions vhich are hazards of the medical profesion should be known to all surgeons, to nurses, and to hospital attendants; and he explosion and fire hazards, together vith their mitigating procedures, should be aught through courses of instruction to ll who engage in operating-room servces. The precautions against the hazards of explosion to be observed by the personel in operating-room practices, and the methods of mitigating the electrification n these hazardous services, have been developed and publicized sufficiently to eave no excuse for ignorance or for egligence in their observance either by hose performing within the dangerous ones or by the administrative staffs who re responsible for hospital equipment and echniques.

The means for reducing to a minimum ire and explosion hazards which originate rom electrostatic causes are

1. In using the closed system of applying he anesthetics, thereby preventing the difusion into the room of the highly explosive apors.

2. In employing a conductive type of flooring or floor covering which should be permanently grounded.

3. In the mandatory use of a conductive ype of footgear on every person engaged in perating-room service.

4. In utilizing only conductive coverings, heetings, and other materials on operating ables.

5. In having the metal operating tables rounded to the conductive flooring by the se of conductive rubber casters or of nultiple short drag chains.

6. In having nurses use conductive clothing throughout so that generated charges are dissipated to ground as rapidly as they are produced.

7. In providing explosionproof electric switches, outlets, lamps, and so forth, and grounded electric parts throughout the operating room.

THE RUBBER INDUSTRY

Various rubber-manufacturing processes in years prior to the present war were sources of high electrification, but the high voltages presented, for the most part, only the minor problems of disagreeable shocks to the operators, rather than of causing serious fire and explosion hazards in plant operations. The advent of synthetic-rubber manufacture during the present war period has caused new techniques to be developed in the processing of rubber products utilizing synthetic rubber largely of the buna and butyl series. Since the rubber industry now embraces the manufacture of the synthetic rubber, as well as its fabrication into the multitude of products, the problems of electrification and the resulting hazards of fires and explosions have been enormously multiplied in each of these two major divisions of industrial operations.

The manufacture of synthetic rubber is essentially a chemical process, in which the fundamental raw materials, whether they be of the petroleum family or of the alcohol group, are converted into intermediate components which are highly volatile and flammable, such components being ethylene, vinyl chloride, vinyl acetate, ethyl benzene, butadiene, styrene, isoprene, and the many others. These constituent products because of their insulating properties are in themselves, or in combination with other substances, highly susceptible to electrification; and through their vaporous states, they are readily ignited even from relatively feeble electric sparks. In attempting to control the electrification, the grounding of mixers, stills, and other chemical apparatus is essential, and the dissipation of the electric charges should be achieved in whatever ways are most readily adaptable to the processes. In addition to the conventional methods of controlling the electrification, the use of inert ambient atmospheres as a dilutant for escaping flammable vapors, such as encasing the pipe lines which carry highly flammable liquids or vapors within inert gas-filled outer pipes, may offer mitigating possibilities and safety practices not as yet utilized to advantage.

Where synthetic rubbers are employed in the fabrication of automotive tires, airplane and tank parts, and rubber-cement compounds, to mention only a few processes, the volatile vapors that are gradually given off from the entrained solvents within the synthetic rubber, or from the solvents which are directly applied in the processing, constitute potential sources of fires and explosions from electrostatic sparks. The solvents commonly employed in treating the synthetic rubbers are gasoline, benzene, naphtha, toluene, zylene, acetone and carbon disulphide, all of which are highly volatile and readily flammable—a hazardous condition that is especially marked in the case of carbon disulphide, with its low boiling temperature of 114 degrees Fahrenheit, since it has an explosive range from 1 to 50 per cent by volume with air.

In addition to thorough grounding of all processing-machine parts, including calender rolls, idler rolls, Banbury mixing paddles, and innumerable moving parts, the generated electric charges will require control by other methods. Humidification has been found by the author to augment electrification in certain processes of high-temperature drying, and thus, it has its limitations as a mitigating agent, here, as in other industries. Where the rubber is calendered onto cotton or rayon fabric, the adhesive properties between the rubber and the fabric are weakened by humidity of sufficient magnitude to mitigate the electrification. In some of the manufacturing stages, the processed rubberized stock is so highly heated that moisture, even from an excessively humid atmosphere, cannot condense upon its surface and thereby lower its surface and volumetric resistivities.

The conduction of charges to ground from inherently insulated products may be accomplished in certain favorable operations by applying lightly contacting conductive brushes. Where particularly perverse cases of otherwise-unmitigated electrification arise, ionizing units of one kind or another may be employed to advantage. In the operation of these units, the air is ionized by collision into positively charged molecules and into electrons within the immediate vicinity of the electrified product. The desired reduction in electrification of the processed material results from the electric charges on the product attracting the oppositely charged ions of the air.

Thorough bonding and grounding of the parts of the machines are of primary importance as a first step in the procedure of controlling the electrification. If fabric stock is running through a machine slowly, while it is being humidified by wet steam, say from steam jets, the charges may be enabled to dissipate themselves to the rolls and, through them, to ground. The author has measured voltages of 15,000 to 80,000 volts from the stock to ground under many conditions, such as in the rewinding of rolls of cotton cloth, in the calendering of rubber stock, in the embossing of wallpaper, or in the drying of rubber-proofed cloth.

In this latter case several fires occurred daily in rubber-cement spreading machines of the type shown in Figure 6. The volatile vapors of the solvents in the synthetic rubber cements, such as toluol, zylene, naphtha, gasoline, benzene and other hydrocarbons, ether, and alcohol solvents, all being heavier than air, settled downward to the floor under and around the spreader. The proofed fabrics, after running over idler rolls above the drying coils to the windup roll, become charged to high voltage. Naturally any intense electric sparks occurring here cause fires to be originated. Antistatic generation was found an effective means of electrostatic control in this process, although its maintenance and supervision required frequent attention. By this method, the idler rolls of the spreading machine were covered with a fabric of the type which was found to generate practically zero contact potential with the rubber-coated stock. Later these machines were enclosed in solvent-recovery units whereby the solvent-vapor–air mixtures were attenuated well below the flammable ranges of the solvents. In this way the elimination of the fire hazards from electrification occurred as a by-product of the operation of the solvent-recovery system—thereby solving both problems simultaneously.

SUMMARY ON GROUNDING

The foregoing characteristics of electrostatic behavior in the few typical industrial processes which were cited, and there are others too numerous to mention, can well serve as a basis for formulating certain conclusions regarding the effectiveness of grounding as a means of mitigating static electricity.

1. All stationary parts of machinery which are employed in processes where static electricity is generated should be permanently grounded, not only to provide safety to operators, but also to prevent differences of potential to grounded members or to other machines.

2. Rotating parts of such machinery should also be grounded, using a suitable form of grounding brush to bear on the rotor or shaft, as otherwise a difference of potential of several thousand volts may exist between the rotating and stationary parts of the machine. In addition to the fire hazards from such sparking, the lubricating properties of the oil in the bearings may be gradually destroyed by the production of acids which occurs from their chemical reaction with the ozone from electrostatic corona and sparks. In some cases where sparks have struck through the oil films of bearings of ungrounded rotors, the bearing surfaces have been prematurely deteriorated by roughening.

3. Where explosive atmospheres pervade wooden buildings or lurk around out-of-doors structures or equipment, all metal parts such as metal roofs, tanks, wire fences, railway sidings, bodies of rubber-tired vehicles, and the many others should be grounded in order to discharge, harmlessly, whatever electrification was produced originally by induction but which later became released as unbound electricity by the dissipation of the inducing charge.

4. Grounding wires should be so installed as to be protected adequately against inadvertent breaking, or otherwise a most effective spark gap may be unsuspectingly established between the concealed ends of the broken wire, and thus, a particularly hazardous situation may obtain when grounding discharges occur.

5. Where electrostatic generation is produced on rapidly moving stocks of the types that are inherent insulators, such as paper, textiles, power and conveyor belts, and rubberized fabrics, all grounded objects which are near such electrically charged products provide sparking hazards; if possible, such grounded objects should be removed to safe distances in order to prevent inadvertent jumping of sparks.

6. Obviously the sparking hazards incidental to the electric charges that are developed on rapidly moving stocks, as enumerated previously, cannot be removed by the grounding of idler rolls, calender drums, and other processing parts of the machines, but the grounding of the machine parts plays an important role in limiting the otherwise sporadic rises of potential above that of ground where recommended grounding practice is not observed.

7. The temporary grounding of portable equipment during certain operations in the presence of flammable ambient atmospheres may constitute a highly dangerous practice, unless approved grounding methods are employed. Such hazards of fires and explosions are peculiarly characteristic to those operations in which small quantities of solvent liquids are employed in mixing rubber cements and printing inks, in operating extractor units in certain chemical operations, and the like, where solvents are bucketed from one location to another. Here floors, personnel, machines, and buckets should be scrupulously maintained at ground potential at all times, as safety measures in avoiding the insidious occurrence of sparks, fires, and explosions.

DANGER IN UNFOUNDED REMEDIES

In conclusion, the author, as a safety engineer, would be negligently remiss in his obligations to industrial management and to plant engineers by omitting to call their attention to the dangers and fallacies which can be concealed in the ill-advised practice of applying cure-alls for the elimination of electrostatic ills within their plant processes.

These very people would abhor vehemently the wily suggestion of employing a proprietary "quack curative" for treating their personal ills, and they would be wise indeed to renunciate as vigorously the use of inexperienced initiates in trying to apply palliatives to their industrial electrostatic hazards—potential dangers as they are which may lead to damage or destruction of physical plant, to injuries or even deaths of personnel, to loss of community good will, and to costly sabotage of industrial operations.

The solutions to such problems of fire and explosion hazards arising from the electrostatic ills of the industrial plants are developed and evolved as the culmination of a systematic program of diagnoses of the conditions, of quantitative investigations of all the pertinent physical factors, and of specialized applications of mitigating devices and techniques.

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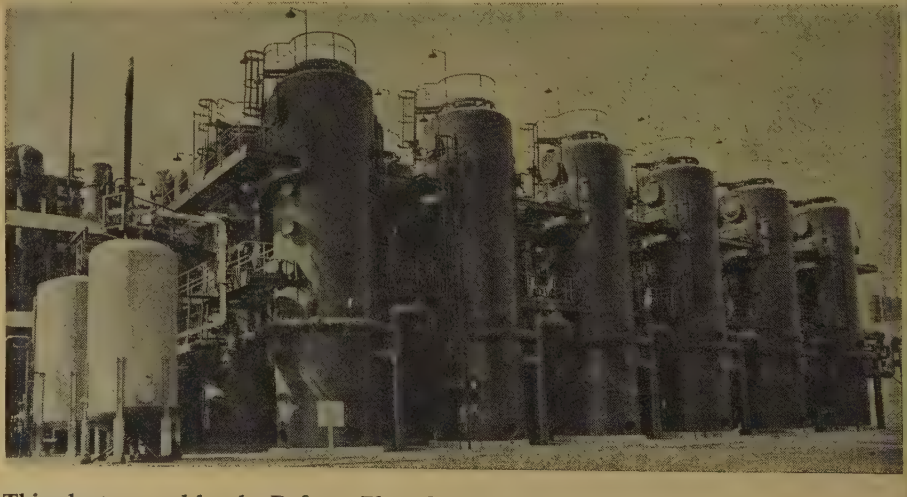

This plant, owned by the Defense Plant Corporation and operated by the Carbide and Carbon Chemicals Corporation, produces butadiene from alcohol

INSTITUTE ACTIVITIES

President Powel Delivers Annual Address in New York

Members of the AIEE New York Section had the unusual opportunity of hearing the annual address of Charles Alfred Powel, president, AIEE, in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York, N. Y., on April 10. This address is normally delivered at the summer technical meeting. Mr. Powel's talk will be published in an early issue of *Electrical Engineering*. George B. Hoadley, chairman, New York section, Institute of Radio Engineers, delivered an address on microwave radio-communication.

The interest of the meeting was further heightened by the showing of two United States Army war films, one depicting the reconstruction of Cherbourg Harbor and the other showing life in bombed German cities taken from captured German films.

Annual Index for 1944 Is Available on Request

As announced (*EE, Mar '45, p 121*) the 1944 index to *Electrical Engineering* and AIEE *Transactions* is being issued in limited edition, available upon written request. The decision to publish the index in limited edition and distribute it separately is a departure from the usual practice of mailing the annual index with *Electrical Engineering* as section 2 of an early issue of the succeeding year. The new procedure represents a further step in the conservation of the restricted supply of paper.

Copies of the index are being mailed without request to all members of AIEE technical committees. In addition, copies are being sent to all subscribers to *Electrical Engineering* and to the "Supplement to *Electrical Engineering*—Transactions Section." To others copies are available without charge and can be obtained by writing to the AIEE order department, 33 West 39th Street, New York 18, N. Y.

Annual Meeting

The annual meeting of the American Institute of Electrical Engineers will be held in the Engineering Societies Building, 33 West 39th St., New York, N. Y., at 10 a.m., Wednesday, June 27, 1945.

At this meeting, the annual report of the board of directors and the reports of the committee of tellers on the ballots cast for the election of officers and for the proposed amendments to the AIEE constitution will be presented. The Lamme Medal will be presented to S. H. Mortensen, and awards of Institute prizes will be announced.

Such other business, if any, as properly may come before the annual meeting may be considered. The officers are not aware that any such other business will be presented.

On account of the Governmental restrictions on conventions, the summer technical meeting, at which the business meeting is normally held, was canceled. Therefore, the annual meeting is to be held at Institute headquarters, and it is expected that the number of out-of-town members attending will be below 50.

(*Signed*) H. H. HENLINE
National Secretary

Fortescue Fellowship Awarded Morton M. Astrahan, the Winner

Morton M. Astrahan, at present attending Northwestern Technological Institute, has been designated the winner of the AIEE Charles LeGeyt Fortescue Fellowship. Mr. Astrahan is a veteran of the present war discharged because of injuries. Before serving in the Army he completed two semesters at Purdue University. After his discharge he entered Northwestern Technological Institute in November 1943 and expects to receive his bachelor of science in electrical engineering in October of this year. His plan is to enter the California Institute of Technology the end of October, and the expenses for the first semester at that institution will be covered by Government aid. The Fellowship award is to cover his second semester at California Institute.

As a memorial to Charles LeGeyt Fortescue, the Westinghouse Electric and Manufacturing Company set up in 1939 a trust fund of $25,000 to provide graduate fellowships in electrical engineering, to be awarded each year by a committee of AIEE. The awards provide a minimum allowance of $500 each.

SECTION • • • • • •

New Technical Groups Formed at Kansas City

Three technical groups, namely, the electronics, industrial electrical practices and problems, and the personal development of the engineer, have been formed by the AIEE Kansas City Section. The electronics group is headed by C. C. Yates (M '42) of the Southwestern Bell Telephone Company. The first meeting already has been held, and the plan is to meet every month for active discussion. The industrial-practices group chairman is N. A. Kieb (M '43) of Pratt and Whitney Aircraft Corporation. This group also plans to have discussions and to use as a text the recent AIEE publication entitled "Electric Power Distribution for Industrial Plants." B. J. George (M '43) of the Kansas City Power and Light Company heads the personal development group. Mr. George intends to raise for discussion the questions of ethics, the ability of an engineer to speak for himself, the professional registration of engineers, and other allied matters.

Michigan Electronics Group Studies Speed Counter. Circuits of electronic instruments was discussed at the first meeting of the newly formed electronics group of the AIEE Michigan Section held in Detroit on March 28. A high light of the occasion was the presentation of instruments for the production-checking of rectifier ripple voltage and for inspection of insulation and arrangement of aircraft wiring harness. An electronic speed counter, utilizing engine ignition as an indication of engine speed, was demonstrated by Paul Huber, assistant director of the General Motors Corporation proving grounds. One hundred persons attended, including 45 AIEE members.

Minnesota Aerotechnical Group Supplies Aero Information

The aerotechnical group, AIEE Minnesota Section, was organized at the beginning of the 1944–45 program to fill the need for discussions on aeronautical subjects. Two Section meetings have been held by the group. The first covered the subject of aircraft electric power plants and distribution problems which was discussed by Colonel T. B. Holliday (M '43) of Wright Field and the second meeting, addressed by W. H. Gille (A '31) of the Minneapolis-Honeywell Regulator Company, covered the subject of aircraft electronics. Slides, motion pictures, operating mock-ups, and samples of apparatus made the programs alive and interesting.

An effort is being made to diversify the programs by organizing special groups and making them responsible for the discussions affecting their particular fields. This is done by planning the organization of a group around one member. The Section chairman chooses a strong man for group chairman and gives him full authority to go ahead and produce results. The group chairman then selects at least two other members to work along with him. Subjects for future programs will include more detailed discussions of aircraft generators and distribution systems, motors for various applications, switchgear, and some of the many different control devices.

Subjects for future programs will include more detailed discussions of aircraft generators and distribution systems, motors for various applications, switchgear, and some of the many different control devices.

PERSONAL • • • •

W. C. Miller (M '26, F '43) superintendent, electrical system, the Detroit Edison Company, Detroit, Mich., has retired after a service record of 45 years. He received his bachelor-of-science degree in electrical engineering from the University of Michigan in 1900 and then entered the employ of the Edison Company as a line and meter engineer. He subsequently held the positions of electrical engineer and assistant and acting general superintendent, and in 1926 became superintendent of electrical system. **H. W. Collins** (A '22, M '42) formerly chief assistant to Mr. Miller, has been named superintendent. Mr. Collins attended the University of Michigan and in 1919 became instructor in the electrical-engineering department. He began working for the Detroit Edison Company in the same year as a field tester, in 1926 receiving the title of relay engineer. In 1929 he became Mr. Miller's assistant and in 1930 was also named project engineer. **D. D. Chase** (A '29, M '39) a member of the company's system engineering staff, succeeds Mr. Collins and becomes his assistant. Mr. Chase received his bachelor-of-science degree in mechanical engineering in 1923 from Kansas State College. Following graduation he was employed by the General Electric Company, Schenectady, N. Y., and became an engineer in the planning division of the electric system of the Edison Company in 1941.

C. W. DeForest (A '07, F '36) vice-president of the Columbia Engineering Corporation, New York, N. Y., and its affiliate, the Cincinnati (Ohio) Gas and Electric Company, has retired. Mr. DeForest gained his early experience with the Brooklyn Edison Company; the United Electric Light and Power Company, New York; and the General Electric Company, Schenectady, N. Y. His association with the Columbia organizations followed its acquisition of the Cincinnati, Newport, and Covington (Ky.) Light and Traction Company of which he was chief engineer from 1903 to 1914. Mr. DeForest then was transferred to the Union Gas and Electric Company, Cincinnati, as electrical engineer. Soon after, he was made manager of the electrical department and vice-president in charge of engineering and operation. Appointed vice-president of the Columbia Power Company in 1925, he later became chief engineer of the Columbia Engineering and Management Corporation, and, when this was liquidated, he returned as chief engineer to the Union Gas and Electric Company. When in 1938 the Columbia Engineering Corporation was formed, he was given charge of the electrical division.

L. T. Rader (A '34, M '43) formerly design engineer, industrial-control engineering department, General Electric Company, Schenectady, N. Y., has accepted the position of director of the department of electrical engineering, Illinois Institute of Technology, Chicago. He was graduated from the University of British Columbia with the degree of bachelor of applied science, electrical engineering, in 1933, and later received the degrees of master of science and doctor of philosophy in electrical engineering, from the California Institute of Technology. After a period with the Canadian Electric Manufacturing Company, Vancouver, British Columbia, Canada, Doctor Rader entered the test department of the General Electric Company in 1937. In 1938, he was transferred to the engineering general department and was given rotating assignments to industrial-control, aeronautics and marine, and induction-motor departments, where he did analysis of special problems and factory contact work, and assisted in the advanced course. In 1939, Doctor Rader designed a-c and d-c solenoids and electromagnets in the industrial-control engineering division, and in 1943 was appointed section head.

E. G. Eidam (A '18) formerly chief telephone engineer, Stromberg-Carlson Telephone Manufacturing Company, Rochester, N. Y., has been made consulting engineer. Mr. Eidam joined the Stromberg-Carlson Company after graduation from the University of Illinois in 1904. **H. R. Reed** (A '28, M '34) succeeds Mr. Eidam as chief telephone engineer. Doctor Reed attended the University of Minnesota, South Dakota State College, and the University of Iowa. In 1929 he became an electrical tester for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and served as professor of electrical engineering, Michigan College of Mining and Technology, Houghton, from 1929 until 1932. In 1930, Doctor Reed served as engineer with the United States Army Corps of Engineers and in 1939 worked in a similar capacity with the National Park Service of the United States Department of Interior. Doctor Reed joined the Stromberg-Carlson Company in 1944, after three years as professor of electrical engineering at the University of Iowa, Iowa City.

Adam Pen-Tung Sah (A '35, F '45) president of the National University of Amoy, Fukien Province, China, has been named visiting professor of electrical engineering at Stanford University, Palo Alto, Calif. He will teach a class in a-c machinery to soldier students enrolled in the Army Specialized Training Program. Doctor Sah was graduated from Stanford University in 1924 with a degree in mechanical engineering. Later he studied at Worcester Polytechnic Institute in Massachusetts from which he received the degree of doctor of science. Returning to China in 1928, he was professor of physics and engineering at Tsing-hua University in Peiping for nine years. He returned to the United States on leave for one year in 1935 during which time he did electrical research at Stanford and was a visiting lecturer at Ohio State University and Massachusetts Institute of Technology. He is the author of a book on dyadic analysis and has recently completed the manuscript for a second book on a-c machinery.

C. T. Sinclair (A '19, F '36) chief distribution engineer, Duquesne Light Company, Pittsburgh, Pa., has been appointed chief engineer of the engineering and construction department. Mr. Sinclair was graduated from Lehigh University in 1917 with a degree in electrical engineering. He entered the employ of the Duquesne Company in 1925 as supervisor of transmission and distribution engineering, and later became electrical engineer in the engineering and distribution department. He now is serving on the AIEE Standards committee and American Research Committee on Grounding. **F. S. Brown** (A '12, M '27) electrical engineer, stations division, was made engineer in charge of the electrical-engineering department. He will direct the station, transmission, distribution, customer, and general engineering divisions. A graduate of Worcester Polytechnic Institute in 1907, Mr. Brown came to the Duquesne company in 1910.

W. A. Gentry (M '43) formerly consultant for the Office of War Utilities of the War Production Board, Washington, D. C., has been appointed assistant to the vice-president in charge of operation of the Indianapolis (Ind.) Power and Light Company. Mr. Gentry was first employed with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1914 and since that time has been employed by electric utility companies in New York, N. Y., Duluth, Minn., and Charlotte, N. C. He was superintendent of the Memphis (Tenn.) Power and Light Company from 1925 to 1939, and from 1939 until he went to Washington in 1942 he held that position with the City of Memphis.

C. H. Shaw (M '39) consulting engineer, Jackson Heights, N. Y., has joined the firm of Shaw-Rutan, Inc. (formerly Rutan and Snead), New York, N. Y., as president. Mr. Shaw, a 1910 graduate of Massachusetts Institute of Technology, commenced his career with the General Electric Company, which he served from 1910 to 1914 in Cleveland, Ohio. After service as a captain with United States Corps of Engineers in World War I, he was associated for a brief period with the New England Power Company, Worcester, Mass., and Jackson and Moreland, Boston. From 1921 to 1933 he was engineer with the New York Edison Company. Since 1934 he has practiced as a consulting engineer.

George H. Woodard (M '42) has been appointed manager of the newly formed aviation gas-turbine division of the Westinghouse Electric and Manufacturing Company with headquarters in South Philadelphia, Pa. He was formerly manager of the company's new-products division at East Pittsburgh, Pa. Mr. Woodard was born in Schenectady, N. Y., and was graduated from Cornell University in 1928 with a degree in mechanical engineering. He was a development engineer with the Ingersoll-Rand Company in Phillipsburg, N. J., until 1936, when he joined the Westinghouse Company as new-products engineer at the company's steam division in South Philadelphia. In 1941 he was made manager of that division.

E. T. Carlson (A '35) formerly manager of the Norwood (Ohio) division of the Trumbull Electric Manufacturing Company, has been made president of the company. Mr. Carlson was graduated from Northeastern University in 1925, and, after serving as instructor at the university for one year, joined the

Hixon Electric Company as purchasing agent and estimator in 1926. In 1928 he became sales engineer for the Trumbull Company in Boston, Mass., and in 1933 was transferred to Ludlow, Ky., as sales manager. He has been manager of the Norwood division since 1941

T. B. Holliday (A '41, M '43) lieutenant colonel, United States Army, Wright Field, Dayton, Ohio, has been promoted to colonel. Colonel Holliday was at one time instructor, physics department, Purdue University, and was then employed at Wright Field, Dayton, Ohio, where he was junior and later assistant electrical engineer.

J. F. Bailey (A '29, M '35) president of the Georgia Power and Light Company, Valdosta, has also been named a vice-president and director of the Florida Power Corporation, St. Petersburg, where he will make his headquarters.

A. C. Streamer (A '10, M '41) vice-president, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been elected president of the National Electrical Manufacturers' Association.

A. S. McCordick (M '30) vice-president, Moloney Electric Company of Canada, Toronto, Ontario, has been elected a vice-president of the recently organized Canadian Electrical Manufacturers' Association.

A. B. Cooper (M '16, F '33) general manager and vice-president, Ferranti Electric, Ltd., Toronto, Ontario, Canada, has been elected president of the newly formed Canadian Electrical Manufacturers' Association.

C. F. Kettering (A '04, F '14) vice-president in charge of research, General Motors Corporation, Dayton, Ohio, has been elected president of the American Association for the Advancement of Science.

Rolf Selquist (A '25) electrical engineer, Copperweld Steel Company, Glassport, Pa., has been appointed consulting engineer for the company. Mr. Selquist had been electrical engineer since 1928.

T. D. Reimers (M '36) formerly electrical superintendent, Consolidated Edison Company of New York, Inc., N. Y., has been appointed engineering manager of Sheldon Service Company.

L. F. Griffith (M '33) formerly an engineer for the Federal Power Commission, Washington, D. C., has rejoined the staff of the Petroleum Machinery Corporation, New York, N. Y., as a power engineer.

P. B. Stewart (A '25) superintendent, electric-distribution department, Cincinnati (Ohio) Gas and Electric Company, has resigned to go into the appliance business in suburban Cincinnati.

E. H. Hammond (A '34) special representative, United States Civil Service Commission, Los Angeles, Calif., has joined Western Insulated Wire, Inc., Los Angeles, as manager of sales and field engineering.

OBITUARY • • • • •

Rollin Nichol Conwell (A '15, F '31) transmission and distribution engineer, Public Service Electric and Gas Company, Newark, N. J., died April 14, 1945. Mr. Conwell, who was born February 10, 1885, in Anderson, Ind., attended Purdue and George Washington Universities between 1904 and 1908. Immediately afterwards he conducted acceptance tests and duty trials of the pumping machinery of the Sewer Department of the District of Columbia. In 1911 he joined the Public Service Company as a laboratory assistant. He was named assistant engineer in 1917, transmission engineer of the substation department in 1922, and transmission and substation engineer in 1926. Since 1938 he had been transmission and distribution engineer. Mr. Conwell, inventor of electric relay systems in widespread use, is credited with building up the present high-voltage transmission system of the Public Service Company, which he completely redesigned and reconstructed. He was prominent in organizing the company's system of load forecasting. Mr. Conwell was the author of numerous papers dealing with transmission-line protection problems, one of which he prepared for the World Power Conference held in Japan in 1929. He received the 1931 AIEE national prize for best paper in engineering practice as coauthor of the paper, "Status of Development and Research on Low-Frequency Induction." Extremely active in Institute affairs, Mr. Conwell served on the following committees: telegraphy and telephony, 1922–24; protective devices, 1924–25; safety codes, 1924–27; power transmission and distribution, 1922–37; communication 1928–32; publication 1933–36; co-ordination of Institute activities, 1933–37; award of Institute prizes, 1933–36 (chairman 1933–35); constitution and bylaws, 1935–39 (chairman, 1935–37); and Lamme Medal, 1941–42. He was chairman of the technical-program committee from 1933 to 1935 and represented the AIEE on the American Committee on Marking of Obstructions to Air Navigation from 1933 to 1937 and on the Alfred Noble Prize Committee from 1934 to 1936. He was a member of the special committee on the question of sponsoring discussion on social and economic subjects in 1935. Mr. Conwell held a number of patents in the United States, Canada, and Great Britain, and was a member of many committees of the National Electric Light Association, the American Standards Association, the National Fire Protection Association, and the Association of Edison Illuminating Companies. He also served on the American Committee on Inductive Co-ordination and the Joint General Committee of NELA and the Bell System.

Harvey Morse Cushing (A '06, F '35) consulting engineer, Buffalo Niagara Electric Corporation, Buffalo, N. Y., died January 31, 1945, at Buffalo. Born December 5, 1875, in Rockport, Ind., Mr. Cushing was graduated with the degree of bachelor of science in electrical engineering from the Massachusetts Institute of Technology in 1899. Following graduation he was placed in charge of installing the electric power and light plant for the Janney Manufacturing Company's Works, Ottumwa, Iowa, and in 1900 worked as tester in the dynamo and motor department of the Western Electric Company Chicago (Ill.) factory. In that same year, he became associated with the General Electric Company, Schenectady, N. Y., in the testing department, in 1904 was transferred to the New York sales department, and subsequently served as engineer trouble shooter in the manufacture of apparatus. In 1910 he was appointed local sales engineer for the Buffalo office. In 1915 Mr. Cushing became mechanical engineer, in charge of steam and mechanical design, for the Buffalo (N. Y.) General Electric Company. In 1922 he was appointed chief engineer of that company, and in 1937 was acting in the same capacity for Buffalo Niagara Electric Corporation, where he later became consulting engineer. Mr. Cushing was a member of the AIEE committee on power generation, and a member of the American Society of Mechanical Engineers and American Society for Testing Materials.

Joseph William Herman (A '07) electrical engineer, electrical design department, Burns and Roe, Inc., New York, N. Y., died March 30, 1945. Mr. Herman was born in Riga, Latvia, on August 1, 1883, and became an American citizen in 1905. He was graduated from Cooper Union in 1905 with the degree of bachelor of science, receiving the electrical-engineering degree in 1912. He began work with the General Electric Company, Schenectady, N. Y., in 1905 in the switchboard drafting department. In 1907 he joined the New York (N. Y.) Edison Company as an electrical draftsman and checker, and worked in a similar capacity with Westinghouse, Church, Kerr and Company of New York, and the Electric Bond and Share Company, New York. In 1912, he became chief electrical designer for the Pearson Engineering Corporation, New York, and was then employed in the same capacity by the Chile (South America) Exploration Company. In 1931 he joined the Electric Management and Engineering Corporation, New York, working in electrical design, and was subsequently connected with Gibbs and Hill, New York, specializing in substation design for railroad electrification. Mr. Herman was employed as electrical engineer by Burns and Roe, Inc., in 1936 and was in charge of the electrical design of several modern steam generating stations.

Harry H. Adams (A '06, M '20) former superintendent of shops and equipment for the Chicago (Ill.) Surface Lines, died January 31, 1945, in Evanston, Ill. He was born January 7, 1871, in Jersey City, N. J., and received the degree of mechanical engineer in 1893 from the Stevens Institute of Technology. Between the years 1893 and 1900, Mr. Adams was employed with the Consolidated Traction Company in New Jersey, and later the North Jersey Street Railway Company, where he became master mechanic. He left that company in 1901 to become superintendent of shops in charge of rolling stock and buildings for the United Railways and Electric Company, Baltimore, Md. From 1907 until 1912 he was superintendent of shops and equipment for the receivers of the Metropolitan Street Railway Company, New York, N. Y., and then entered the employ of Ford, Bacon and Davis, New York. In 1913, Mr. Adams became associated with the Chicago Surface Lines, retiring in 1944.

Mr. Adams was at one time president of the American Street and Interurban Railway Engineering Association, and chairman of the committee on standards, American Electric Railway Engineering Association. He was a member of the AIEE traction and transportation committee from 1916 until 1918.

Samuel Graham Neiler (A '94, M '95, F '13) consultant engineer, Neiler, Rich and Company, Chicago, Ill., died February 28, 1945, in Oak Park, Ill. Mr. Neiler, who was born in Erie, Pa., November 14, 1866, received his education at the Massachusetts Institute of Technology and the University of Minnesota, studying mathematics and mechanical engineering. From 1889 until 1890, Mr. Neiler was assistant mechanical engineer for the St. Paul and Sault Ste. Marie Railway, Minneapolis, Minn., and in 1891 he became engineer with Thomson-Houston Electric Company, Boston, Mass. From 1892 until 1894, he was assistant electrical engineer, World's Fair Columbian Exposition, Chicago, Ill., and in 1895 became a member of the firm of Pierce, Richardson and Neiler, Chicago. He became president of the firm in 1911, and served in this capacity until 1913, when he became a member of the firm of Neiler, Rich and Company. The latter firm was succeeded by Neiler, Rich, and Bladen of which he was senior partner. He was a member of the American Society of Mechanical Engineers, the Institution of Electrial Engineers (Great Britain), American Society of Civil Engineers, and vice-president and director of the Electrical Association of Chicago.

William Lester Enfield (A '10, M '15, F '32) development and consulting engineer, lamp department, General Electric Company, Nela Park, Cleveland, Ohio, died on March 21, 1945, in Cleveland. Born March 26, 1879, in Chase, Kans., Doctor Enfield received the degrees of bachelor of science in electrical engineering (1909), and doctor of engineering (1938) from Kansas State College, where he later returned to be instructor in physics. He also attended Kansas State Normal School, the University of Chicago, and Massachusetts Institute of Technology. He entered the employ of the National Electric Light Association, Cleveland, Ohio, in 1910 as engineer in the engineering department, and subsequently became engineer of the manufacturing department (1911), manager of the special engineering department (1913), and manager of the lamp development laboratory (1914), continuing in that position when the laboratory became part of the incandescent-lamp department of the General Electric Company. In 1940 he became consulting engineer. He was an associate of the Society of Automotive Engineers, and a member of the Cleveland Engineering Society.

Edwin Jarvis King Mason (A '07) engineer, the Consolidated Edison Company of New York (N. Y.) died February 23, 1945, at Enfield, Conn. He was born at Suffield, Conn., October 23, 1879. He graduated from Trinity College in 1901 and received the master-of-arts degree there in 1903. He also attended the Rensselaer Polytechnic Institute, where in 1904 he became assistant in the department of electrical engineering and physics. He served two years, from 1908 until 1910, as professor of electrical engineering and physics at the University of Pittsburgh, Pittsburgh, Pa., leaving there to become associated with the Consolidated Edison Company. He served first as general foreman in the test department and instructor in the educational bureau. In 1913 he was appointed engineer in the contract and inspection department, and later became assistant manager in the commercial engineering bureau, now known as the commercial technical bureau. After 26 years with the company he retired in 1936.

David Leonard Lindquist (A '04) chief engineer, Otis Elevator Company, New York, N. Y., died November 11, 1945. He was born September 28, 1874, in Stockholm, Sweden, and graduated from the Royal Technical University there. He spent several years as engineer and draftsman in Sweden and two years as a designer in Berlin, Germany. In 1902 he was employed by the Otis Elevator Company, designing and testing, and was later appointed chief engineer. For his achievements he received the John Ericsson Medal in 1940 awarded by the American Society of Swedish Engineers, and in June of the same year was honored by the King of Sweden, who made him a Knight of the Royal Order of Vasa. Mr. Lindquist was active in the American Standards Association, as a member of the committee on the safety code for elevators, dumbwaiters, and escalators, and of the sectional committee on wire ropes for mines.

MEMBERSHIP • • •

Recommended for Transfer

The board of examiners, at its meeting on April 19, 1945, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Anderson, B. E., elec. engr., Ebasco Services, Inc., New York
Currin, H. P., chief elec. engr., Eugene Water Board, Eugene, Oregon
Douglass, F. S., secy.-treas., Laramore & Douglass, Inc., Chicago, Ill.
Kifer, E. H., gen. mgr., City Public Service Board, San Antonio, Texas
Mills, G. A., design and construction engr., Central Pwr. & Lt. Co., Corpus Christi, Texas
Mitschrich, M. F., vice-pres., Moloney Elec. Co., St. Louis, Mo.
Terman, F. E., director, Radio research lab., Harvard Univ., Cambridge, Mass.

7 to grade of Fellow

To Grade of Member

Ballman, E. C., manufacturer, Baldor Elec. Co., St. Louis, Mo.
Bennett, Rawson, Comdr., Navy Dept., Washington, D. C.
Bennett, R. M., asst. design engr., General Elec. Co., Philadelphia, Pa.
Berger, David, secy.-treas., Berger Bros., Toledo, Ohio
Bixby, W. H., assoc. prof. of elec. engg., Wayne Univ., Detroit, Mich.
Bliss, F. W., dist. mgr., General Elec. Co., Boston, Mass.
Brown, W. T., engr., Philadelphia Elec. Co., Philadelphia, Pa.
Browne, T. E., research engr., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Burt, W. P., requisition engr., General Elec. Co., Philadelphia, Pa.
Case, H. M., general inspector, Western Union Telegraph Co., New York
Clayton, M. B., carrier current engr., Tennessee Valley Authority, Chattanooga, Tenn.
Croney, S. I., marine elec. engr., Atlantic Refining Co., Philadelphia, Pa.
Cuffe, R. C., design engr., Electricity Supply Board of Ireland, Dublin, Ireland
Donald, H. G., elec. engr., Lloyd's Register of Shipping, Vancouver, B. C., Canada
Durfee, B. N., supt. of maintenance, Gilbert & Barker Mfg. Co., West Springfield, Mass.
Falls, C. W., engr., General Elec. Co., Schenectady, N. Y.
Floor, Erik, owner, Erik Floor & Associates, Chicago, Ill.
Fowler, E. B., transmission and plant extension engr
Northwestern Bell Tel. Co., Des Moines, Iowa
Hall, P. R., elec. engr., Bessemer Elec. Service, Besseme
Ala.
Hayes, V. J., asst. engr., The Connecticut Light & Pw
Co., Waterbury, Conn.
Hayward, S. K., elec. engr., Northern Indiana Publi
Service Co., Gary, Indiana
Jacobsen, W. E., elec. engr., General Elec. Co., Schenectady, N. Y.
Kent, H. A., product engr., Sperry Gyroscope Co., Grea
Neck, L. I., N. Y.
King, C. F., district engr., Westinghouse Elec. & Mf
Co., Philadelphia, Pa.
Koliss, P. P., member of technical staff, Bell Telephon
Labs., Inc., New York
Loomis, E. W., middle Atlantic district mgr., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Matthias, L. H., director of Research, Allen Bradle
Co., Milwaukee, Wis.
Mortlock, J. R., asst. to supt. engr., British Thomsor
Houston Co., Ltd., London, England.
Muehleman, H. J., operating engr., Hydroelectric Pw
Comm. of Ontario, Toronto, Ont.
Murray, J. D., elec. engr., Victory Aircraft Ltd., Toronto, Ont., Can.
Norberg, H. A., partner-manager, Nelson Elec. Mfg. Co
Tulsa, Okla.
O'Brien, F. J., elec. engr., Tennessee Valley Authority
Knoxville, Tenn.
Ostaff, Wm., radio engr., U. S. Navy Dept., Washington, D. C.
Pepperberg, L. E., engr., Zenith Radio Corp., Chicago
Ill.
Pye, H. C., development & Research engr., Automati
Elec. Co., Chicago, Ill.
Reed, J. R., field engr., National Electric Coil Co
Columbus, Ohio
Scherrer, G. M., ensign, United States Naval Reserve
Shawneetown, Ill.
Schmidt, E. A., owner, E. A. Schmidt & Co., St. Loui
Mo.
Selvidge, H., assoc. prof. of elec. engg., Kansas Stat
College, Manhattan, Kansas
Sinnott, J. F., protection engr., San Diego Gas & Ele
Co., San Diego, Calif.
Sugden, A. C., asst. elec. engr., The Kellex Corp., Ne
York
Tatum, F. W., engr., American District Telegraph Co
New York
Thompson, H. B., watch electrician, Commonwealt
Edison Co., Chicago, Ill.
Wiederkehr, K. P., elec. engr., Allis Chalmers Mfg. Co
Milwaukee, Wis.
Wood, A. C., consulting engr., Stock Exchange Bldg
Philadelphia, Pa.
Wyatt, C. H., distribution engr., Oklahoma Gas & Ele
Co., Oklahoma City, Okla.

46 to grade of Member

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Applications for Election

Applications have been received at headquarters fro the following candidates for election to membership i the Institute. Any member objecting to the election any of these candidates should so inform the nation secretary before June 15, 1945 or August 15, 1945, if th applicant resides outside of the United States or Canad

To Grade of Fellow

Tagg, G. F., English Elec. Co., Ltd., Stafford, Englan

1 to grade of Fellow

To Grade of Member

Archer, W. D., Jr., Gulf Mobile & Ohio R.R. Co
Meridian, Miss.
Baughman, G. W. (Reelection), Union Switch & Si
Co., Swissvale, Pa.
Bischel, H. W., Wis. Gas & Elec. Co., Racine, Wis.
Booth, S. W., U. S. Naval Ord. Lab., Washington, D. C.
Bryan, E. E., Vanderbilt Univ., Nashville, Tenn.
Campbell, F. D., Detroit Edison Co., Detroit, Mich.
Chinn, H. A., Columbia Broadcasting System, Inc
New York, N. Y.
Couy, C. J. (Reelection), Duquesne Light Co., McKee
port, Pa.
Crouse, R. C. (Reelection), Civil Aero. Adm., Washin
ton, D. C.
Entwistle, J. L., Pawtucket, R. I.
Ewing, S. C., Gen. Elec. Co., Schenectady, N. Y.
Fischer, B. A. (Reelection), U. S. Naval Academ
Annapolis, Md.
Godfrey, K. L., Godfrey (Pty.) Ltd., Waterloo, N.S.W
Australia
Goldberg, L. J., Gen. Elec. Co., Schenectady, N.
Helfman, S. J. (Reelection), J. A. Jones Const. Co
Inc., Oak Ridge, Tenn.
Hunter, J. L., Bell Tel. Labs., New York, N. Y.
Kamdar, H. M., Krishnanagar, Bhavnagar, Kathi
wadi, India
Loomis, H. S., Union Switch & Sig. Co., Pittsburgh, P
Marvin, P. R., Mil. Gas Spec. Co., Milwaukee, Wis.
May, J. W., Wright's Automatic Mchy. Co., Durha
N. C.
McCabe, A. M., Carolina Pr. & Lt. Co., Raleigh, N.
McCaw, R. F., Gen. Cable Corp., Rome, N. Y.
McCormick, J. R., N. Y. Bd. of Transp., New Yor
N. Y.
Myers, R. B. (Reelection), Elec. Engg. & Constr. C
Des Moines, Iowa
O'Brien, E. F., Lockheed Aircraft Corp., Van Nuy
Calif.
Overby, H. R. S., Royal Norwegian Min. of Sup.
Reconst., New York, N. Y.
Owen, G. E., Antioch College, Yellow Springs, Ohio

eirson, G. F., Midland Electric Corp., Staffordshire, England
erkins, L. M. (Reelection), Allen Bradley Co., Milwaukee, Wis.
owell, D. A., Iowa Pr. & Lt. Co., Des Moines, Iowa
ritham, C. F. (Reelection), Maine Pub. Serv. Co., Presque Isle, Maine
chmotzer, E. A., N.A.C.A., Cleveland, Ohio
hiffman, J. W., Lt., U.S.N.R., Cleveland, Ohio
hortt, H. L., Airadio, Inc., Stamford, Conn.
mith, J. L. (Reelection), Commonwealth Edison Co., Chicago, Ill.
wain, O. M., Westinghouse Elec. & Mfg. Co., Lima, Ohio
anner, T. J., Eastern Airlines, Miami, Fla.
aylor, C. W., Admiralty Scientific & Tech. Pool, Helensburgh, Scotland
erry, F. M., The Insl-X Co., Inc., Brooklyn, N. Y.
an Zile, L. W., Pub. Serv. Elec. & Gas Co., Irvington, N. J.
Vald, F. O., Utah Pr. & Lt. Co., Salt Lake City, Utah
Varner, A. J., Fed. Tel. & Radio Corp., Newark, N. J.
Veber, R. J., Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.
Vhite, C. H. M. (Reelection), Stone & Webster Engg. Corp., Boston, Mass.
erbi, P. E., Kellex Corp., New York, N. Y.

5 to grade of Member

o Grade of Associate

nited States and Canada

. North Eastern

llen, W. H., New Hampshire Gas & Elec. Co., Portsmouth, N. H.
lvarez, W., Gen. Elec. Co., Schenectady, N. Y.
erda Echaurren, H., Gen. Elec. Co., Pittsfield, Mass.
omerford, T. G., Eastman Kodak Co., Rochester, N. Y.
ooper, B., Gen. Elec. Co., Schenectady, N. Y.
owles, L. B., Gen. Elec. Co., Schenectady, N. Y.
rant, E. T., Gen. Elec. Co., Schenectady, N. Y.
amilton, J. D., Gen. Elec. Co., Schenectady, N. Y.
errick, E., R. I. Card Board Co., Pawtucket, R. I.
elman, W. L., C. & K. Elec. Co., Providence, R. I.
ubler, E. F. (Reelection), Gen. Elec. Co., Schenectady, N. Y.
ockett, R. H., Gen. Elec. Co., Schenectady, N. Y.
McDowell, E. B., Gen. Elec. Co., Schenectady, N. Y.
oulton, K. C., Gen. Elec. Co., Schenectady, N. Y.
elson, J. C., Berger Bros. Elec. Motors, Inc., Rochester, N. Y.
olte, R. J., Westinghouse Elec. & Mfg. Co., Boston, Mass.
erry, W. W., Jr., Gen. Elec. Co., Schenectady, N. Y.
flaum, S. M., Berger Bros. Elec. Motors, Inc., Rochester, N. Y.
osi, L. A., Great American Ind., Meriden, Conn.
eeger, C. L., III, Cornell Univ., Ithaca, N. Y.
ills, E. H. (Reelection), Gen. Elec. Co., Schenectady, N. Y.
timson, A., Gen. Elec. Co., West Lynn, Mass.
tokes, J. H., Maguire Ind., Greenwich, Conn.
roy, J. P., Gen. Elec. Co., Schenectady, N. Y.
yll, J. E., Gen. Elec. Co., Schenectady, N. Y.
Vilbur, B., Gen. Elec. Co., Schenectady, N. Y.
Vitt, E. T. (Reelection), Stone & Webster Engg. Corp., Boston, Mass.
ates, C. G., Jr., Gen. Elec. Co., Schenectady, N. Y.

Middle Eastern

aker, R. S., Goodyear Tire & Rubber Co., Akron, Ohio
aldwin, R. F., Insulation Mfgrs. Corp., Cleveland, Ohio
onnolly, W. J. (Reelection), Safe Harbor Water Pr. Corp., Baltimore, Md.
iederich, N. F., Clark Cont. Co., Cleveland, Ohio
ixon, A., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
yson, W. H., Jr. U.S.C.G. Yard, Curtis Bay, Md.
vans, J. D., Glenn L. Martin Co., Baltimore, Md.
rancis, H. R., Dayton Pr. & Lt. Co., Dayton, Ohio
unk, R. N., Phila. Elec. Co., Philadelphia, Pa.
ilmer, W. F., Lear, Inc., Piqua, Ohio
lycadgis, B. M., Lear, Inc., Piqua, Ohio
ossman, H. G., Dayton Pr. & Lt. Co., Dayton, Ohio
reene, R. W., Penna. Pr. & Lt. Co., Bethlehem, Pa.
rigioni, J. D., Cates & Shepard, Philadelphia, Pa.
eald, S. T., Republic Steel Corp., Cleveland, Ohio
orner, H. V., Glenn L. Martin Co., Middle River, Md.
oxie, E. A., Elec. Storage Battery Co., Philadelphia, Pa.
elley, M. E., Glenn L. Martin Co., Baltimore, Md.
agee, H. E., Lear, Inc., Piqua, Ohio
McClain, H. D., Glenn L. Martin Co., Baltimore, Md.
McLain, W. J., Dayton Pr. & Lt. Co., Dayton, Ohio
McLaughlin, E., Stockwell Transf. Corp., Akron, Ohio
Miller, G. J., Jr., Western Elec. Co., Inc., Baltimore, Md.
agel, E. C., Carbide & Carbon Chem. Co., South Charleston, W. Va.
chneider, E. V., Alliance Mfg. Co., Alliance, Ohio
hannon, W. R., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
herry, R. S., U. S. Navy, Washington, D. C.
an Roekens, N. H., Phila. Elec. Co., Philadelphia, Pa.
Vallace, C., Westinghouse Elec. & Mfg. Co., Baltimore, Md.
Vatkins, N. (Reelection), Carbide & Carbon Chem. Corp., South Charleston, W. Va.
Veadon, R. W., Lear, Inc., Piqua, Ohio
Veiss, M. T., Chief Petty Officer, U.S.N.R., U. S. Naval Lab., Washington, D. C.
Veitzmann, H. P., A. J. LaCourse Elec. Co., Philadelphia, Pa.
Viecking, W. E., Bell Tel. Labs., Inc., Cleveland, Ohio
Volfram, P. K., Insulation Mfgrs. Corp., Cleveland, Ohio
iegler, F. J., I-T-E Circuit Breaker Co., Philadelphia, Pa.

3. New York City

Boudreau, W. F., Carbide & Carbon Chem. Corp., New York, N. Y.
Braunfeld, M. T., J. A. Tuck, Cons. Engrs., New York, N. Y.
Divito, A. (Reelection), E. I. DuPont de Nemours, Arlington, N. J.
Fockler, W. G., Allen B. DuMont Labs., Inc., Passaic, N. J.
Hahn, L. A., Federal Paper Co., Bogota, N. J.
Hayes, A. E., Jr., Hazeltine Electronics Corp., Little Neck, N. Y.
Heberling, W. W., Jr., Kellex Corp., New York, N. Y.
Hoffman, S., National Design Serv., New York, N. Y.
Krajewski, J. J., Arc Elec. Const. Co., Inc., New York, N. Y.
Lewinski, J., Radio Receptor Co., New York, N. Y.
Lobo, E., Arma Corp., Brooklyn, N. Y.
Manning, R. H., Sperry Gyroscope Co., Inc., Great Neck, N. Y.
Mealer, R. J., Western Elec. Co., Inc., Kearny, N. J.
Nagel, L. L., Elec. Testing Labs., Inc., New York, N. Y.
Nystrom, H. W., Fed. Tel. & Radio Corp., East Newark, N. J.
Oldmixon, R., Western Elec. Co., New York, N. Y.
Powell, C. S., Fed. Tel. & Radio Corp., Newark, N. J.
Roberts, A. O., Arma Corp., Brooklyn, N. Y.
Roess, L. C., Texas Co., Beacon, N. Y.
Sargent, J. R., G. S. Armstrong & Co., Inc., New York, N. Y.
Selnick, S., Fed. Tel. & Radio Corp., East Newark, N. J.
Sochacki, F. C., Fed. Tel. & Radio Co., East Newark, N. J.
Wisner, F. C., Western Elec. Co., Inc., Kearny, N. J.
Wong, F., Sperry Gyroscope Co., Garden City, N. Y.

4. Southern

Dennison, W. L., Clinton Engg. Works, Oak Ridge, Tenn.
Dickinson, N. K., Tenn. Eastman Corp., Oak Ridge, Tenn.
Jenkins, L. W., Tenn. Val. Auth., Wilson Dam, Ala.
Lipscomb, J. T., Tenn. Val. Auth., Chattanooga, Tenn.
McLaughlin, J. T., Tenn. Val. Auth., Knoxville, Tenn.
McRae, J. T., Jr., Alabama Pr. Co., Birmingham, Ala.
Melugin, D., Tenn. Eastman Corp., Oak Ridge, Tenn.
Percival, F. G., Knoxville Elec. Pr. & Water Bd., Knoxville, Tenn.
Rose, R. B., Gen. Elec. Co., Richmond, Va.
Roth, A. C., Tenn. Val. Auth., Chattanooga, Tenn.
Seefeld, J., Tenn. Eastman Corp., Knoxville, Tenn.
Senatore, S. J., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Smith, C. E., Bell Aircraft Corp., Marietta, Ga.
Snodderly, Z. K., Tenn. Val. Auth., Chattanooga, Tenn.

5. Great Lakes

Albright, R. W., Westinghouse Elec. & Mfg. Co., Chicago, Ill.
Bischmann, O. A., Pub. Serv. Co. of Northern Ill. Chicago, Ill.
Bostater, A. H., Allen-Bradley Co., Milwaukee, Wis.
Camp, B. G., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Deming, G. T., Clark Equipment Co., Buchanan, Mich.
Dever, C. M., Pub. Serv. Co. of Northern Ill., Waukegan, Ill.
Flores Munoz, V., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Foster, L., Foster Elec. Co., Peoria, Ill.
Gardner, M. L., Delco Remy Div., Anderson, Ind.
Germain, G. B., Westinghouse Elec. & Mfg. Co., Duluth, Minn.
Hamilton, R. C., Wis. Tel. Co., Milwaukee, Wis.
Hesse, L., Gisholt Mach. Co., Madison, Wis.
Hewett, J. L., Harza Engg. Co., Chicago, Ill.
Hoelzl, E. A., H. N. Whittelsey Inc., Chicago, Ill.
Kaldenberg, W. G., Iowa Pr. & Lt. Co., Des Moines, Iowa
Kranzush, A. H., Square D Co., Milwaukee, Wis.
Krefting, E., Foster Elec. Co., Peoria, Ill.
Mahn, G. R., Gen. Elec. X-Ray Corp., Chicago, Ill.
Maier, I. W., Sampsel Time Control, Inc., Spring Valley, Ill.
Martin, D. R., Westinghouse Elec. & Mfg. Co., Davenport, Iowa
Meilicke, E. E., Square D Co., Milwaukee, Wis.
Miron, V. C., Wincharger Corp., Sioux City, Iowa
Oakley, T., Ill. Pr. Co., Belleville, Ill.
Oehlwein, O. L. (Reelection), Pub. Serv. Co. of Northern Ill., Chicago, Ill.
Oestreicher, S., Harnischfeger Corp., Milwaukee, Wis.
Peterson, N. L., Cutler-Hammer, Inc., Milwaukee, Wis.
Robel, J. H., Gen. Elec. Supply Corp., Des Moines, Iowa
Sacco, E. J. (Reelection), Westinghouse Elec. & Mfg. Co., Chicago, Ill.
Sachse, E. G., Sr., General Contracting, Peoria, Ill.
Sahlberg, J. M., Pub. Serv. Co., Northern Ill., Waukegan, Ill.
Schultz, F. E., Royal Elec. Mfg. Co., Chicago, Ill.
Selsdorf, J. D., Pub. Serv. Co. of Northern Ill., Chicago, Ill.
Swanson, E. S. (Reelection), Pub. Serv. Co. of Northern Ill., Chicago, Ill.
Tapper, H. A., Wis. Elec. Pr. Co., Milwaukee, Wis.
Taylor, R. W., Communications Dept., Chanute Field, Ill.
Tyndall, J. J., Pub. Serv. Co. of Northern Ill., Waukegan, Ill.
Van Duser, C. E., A-C Supply Co., Inc., Milwaukee, Wis.
Vater, G. W., Allen-Bradley Co., Milwaukee, Wis.
Woodward, R. V., Dowzer Elec. Mchy. Works, Mt. Vernon, Ill.
Wright, P. H., Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.

6. North Central

Fuller, J. F., Gen. Elec. Co., Denver, Colo.
Kiesling, P. W., Pub. Serv. Co. of Colo., Denver, Colo.

7. South West

Cecchetti, F. (Reelection), Rural Elec. Adm., St. Louis, Mo.
Corcoran, A. E., Transcontinental & West. Air, Inc. Kansas City, Mo.
Green, R. L., Dick X-Ray Co., St. Louis, Mo.
McClure, R. F. (Reelection), Southwestern Pub. Serv. Co., Plainview, Texas
Peterschmidt, J. E., Walco Engg. & Const. Co., Tulsa, Okla.
Ury, J. M., Curtiss-Wright Corp., Robertson, Mo.

8. Pacific

Beeson, M. L., County of Los Angeles, Los Angeles, Calif.
Brettell, G. A., Jr., Univ. of Calif., San Diego, Calif.
Demaree, D. M., Goodyear Aircraft Corp., Litchfield Park, Ariz.
Edgecomb, H., Moore Dry Dock Co., Oakland, Calif.
Gustovich, G., Westinghouse Elec. & Mfg. Co., Los Angeles, Calif.
Haines, A. S., Marine Corps Air Depot, San Diego, Calif.
Hoskins, J. W., Sup. of Shipbldg., U. S. Navy, San Francisco, Calif.
Hoyt, F. R., W. E. Camp, Sacramento, Calif.
Kastl, R. H., U. S. Navy, San Francisco, Calif.
Knowlton, C. R., Lt. Comdr., U.S.N.R., San Diego, Calif.
Louie, W. H. W., Calif. Shipbldg. Corp., Wilmington, Calif.
Mack, C. D., San Diego Gas & Elec. Co., San Diego, Calif.
Moninger, M., Southern Calif. Tel. Co., Los Angeles, Calif.
Nassir, N., C. F. Braun & Co., Alhambra, Calif.
Oberholtzer, J. M., North American Avia., Inglewood, Calif.
Pabst, R. E., Westinghouse Elec. & Mfg. Co., Los Angeles, Calif.
Rains, S. D., U. S. Navy, Hunter's Point, Calif.
Suykerbuyk, C. P., Allis-Chalmers Mfg. Co., Manhattan Beach, Calif.
Waller, J. E., U. S. Navy, Camp Parks, Calif.
Ward, P. E., Sacramento Air Serv. Tech. Comm., Sacramento, Calif.
Webb, A. H., Waugh Labs., Pasadena, Calif.
White, T. D., Cent. Ariz. Lt. & Pr. Co., Phoenix, Ariz.

9. North West

Burdick, R. L., Northwestern Elec. Co., Vancouver, Wash.
Dawson, J. R., Electric Smith Co., Spokane, Wash.
Duryee, S. L., Pac. Tel. & Tel. Co., Seattle, Wash.
Eisele, L. A., Washington Water Pr. Co., Spokane, Wash.
Hammond, W. M. (Reelection), Northwestern Elec. Co., Vancouver, Wash.
Ittner, C. K., Alum. Co. of America, Troutdale, Oreg.
Sargent, M. J., Northwest Electronics Co., Spokane, Wash.
Wolgast, L. H., Alum. Co. of America, Troutdale, Oreg.

10. Canada

Baker, N. W. G., Ontario Hydro Elec. Pr. Comm. Toronto, Ont., Can.
Canniff, F. H., National Defense Dept., Ottawa, Ont., Can.
Carriere, R. J., Allanson Armature Mfg. Co., Ltd., Toronto, Ont., Can.
Duchastel, P. A., National Res. Council, Ottawa, Ont., Can.
Howard, H. A., Brantford Township Hydro Elec. Comm., Brantford, Ont., Can.
Kierans, W. P., Montreal Tramways Co., Montreal, Que., Can.
Stevenson, W. R., National Res. Council of Can., Montreal, Que., Can.
Walker, W. E., Montreal Tramways Co., Montreal, Que., Can.
Wright, C. A., Can. Gen. Elec. Co., Toronto, Ont., Can.

Elsewhere

Beynon, T. C., Forbes Mun. Council, Forbes, N.S.W., Australia
Buckland, E. A., British Thomson-Houston Co., Ltd., Rugby, England
Butterworth, E. G., Elect Lt., R.N.V.R., Bath, England
Chabook, R. D., Hyderabad Elec. Syndicate, Hyderabad, India
Du Toit, P. J., Victoria Falls & Trans. Pr. Co., Transvaal, South Africa
Marcroft, R. L., Ministry of Munitions, Melbourne, Australia
Mazumdar, B. C. (Reelection), Dir. Gen. Shipbldg. & Repairs, Bombay, India
McMullen, W. F., Lt. Col. (Reelection), Canadian Army Overseas, B.W.E.F.
Pollard, A. R., Winchester Corp., Winchester, England
Rammohan, S., Indian Iron & Steel Co., Ltd., Kulti, India
Rao, S. R., Callender's Cable & Const. Co., Bombay, India
Saborio M., J. R., Dept. Elect. Mun. Alajuela, Costa Rica, C. A.
Santonna, A. J., United Provinces Elec. Supply Co., Ltd., Lucknow, India
Selle, E. M., Emp. Elec. del Depto. de Chimaltenango, Guatemala City, Guat., C. A.
Shimmins, A. J., Precision Measurements Gen. Res. Labs., Melbourne, Australia

Total to grade of Associate

United States and Canada, 189
Elsewhere, 15

OF CURRENT INTEREST

Bills Reflect Patent Commission's Recommendations

The National Patent Planning Commission's recommendations (*EE, Sept '43, pp 423–4*) are carried out in three new bills on patents recently introduced in Congress by Representative F. W. Boykin, chairman of the House committee on patents. The major proposal, HR 2632, would require the recording of agreements relating to patents. Another bill, HR 2630, would provide for the public registration of patents available for licensing, and HR 2631 proposes that a patent shall terminate not more than 20 years after an application has been filed but keeping the term of a patent at 17 years.

These bills have been endorsed by the National Association of Manufacturers, whose chairman R. J. Dearborn has gone on record in favor of enlarging the Patent Office staff to permit a thorough examination of every application and thus correct one serious weakness in the system.

WAR PROGRAM ● ●

Tramway Built to Evacuate Wounded on Italian Front

Using for the first time in combat a trick they practiced diligently in the Rocky Mountains, engineers of the tenth "Mountaineer" division recently built a 1,500-foot cable tramway for evacuation of the wounded from the Fifth Army front in Italy. The tram, which carries supplies on the up trip, reduced the average time it takes to evacuate a casualty, from between 3 and $5^1/_2$ hours, to five minutes. The tramway is 450 feet higher on the ridge than it is at its base. Construction of the tram required only nine hours. Suspended from half-inch wire cable supported by two A frames built to sustain ten-ton stress and powered by a gasoline engine, the lift will bear 350 pounds. It is pulled by quarter-inch wire cable. Italian soldiers pioneered in cable tramways during the World War in fighting in the Alps Mountains, where they assembled 1,200 miles of them. Engineers of the Tenth Division studied their methods while in training and built several tramways near Camp Hale, Colo.

Government Needs Electrical Engineers

The United States Civil Service Commission is making an extensive recruiting drive to provide electrical engineers for essential war work in the Signal Corps, in the Bureau of Ships of the Navy Department, in offices of the Rural Electrification Administration, and in various Federal agencies in Washington. Engineers not now engaged in war work are urged to consider these opportunities. The appointments are war service appointments and are made in accordance with War Manpower Commission policies and employment stabilization programs. Applications may be obtained from the Commission's local representatives at first- and second-class post offices throughout the country, or from the Commission, Washington 25, D. C.

Radio–Radar Equipment Discussed. Promoting war production of radio–radar equipment was the principal topic of joint meetings held at the Mount Royal Hotel in Montreal, Canada, on April 25–26 by officials of the United States and Canadian Governments, with the two boards of directors and officers of the American and Canadian Radio Manufacturers Associations. Present also were Army and Navy officers and directors of radio and radar divisions. Mutual problems of the war program and of the American and Canadian industries were discussed, and further co-operation between the neighboring organizations of radio-manufacturers' associations was suggested.

Electric Power Will Hasten Italy's Industrialization

Industrial production in liberated Italy will be increased shortly as additional electric energy becomes available, according to an announcement of the Allied Commission. The increased production will result directly from a larger allocation of power for civilian use. Production of superphosphate fertilizer, carbon bisulphide, cotton and woolen textiles, sewing thread, and other items will be started. At the same time, operation of mercury, sulphur, pyrite and lignite mines will be improved, principally in the area north of Rome between Terni and Florence. The bringing into production of manufacturing and mining operation is made possible because of improved electric output in the area served by the Central Italy Grid System. One larger power plant which will be added to the system will increase the power output by approximately 25 per cent. The Central Italy Grid System covers the area from the Garigliano River (above Naples) to Florence on the north and Ancona and Rimini on the northeast. In one important industrial area electric power available was increased to 33,500 kw in the month of April from 21,000 in March.

Installed electric generating capacity for Central Italy will soon be increased to 285,000 kw, an increase of 40 per cent in two months, bringing it to a level more than five times what it was when this region was liberated. This increased capacity, however, does not yet compare with prewar capacity of 1,292,336 kw.

Telephone Facilities of Liberated Countries Are Restored

United States Army Signal Corps soldier are rehabilitating telephone facilities of liberated European cities for the use of Allied Armies as they move forward. European cities customarily utilize sewers as conduits for telephone cables, but officers and enlisted men put on hip boots and carry out essential repairs and make new installations. Numerous cities, in France especially, have been brought into adequate and reliable contact with the directing agencies and with the battlefronts, thus serving as added links in the expanding system of military communications serving the western front. The use of sewers for telephone cables is prompted by Europe's perennial need to be economical in all civic installations. In American cities such underground cables usually are installed in vitrified clay conduits providing ducts only slightly larger than the cables which are pulled through by means of wire. Manholes are located on the duct lines approximately a city block apart, permitting splicing at convenient points. In the sewers of France the lead cables are merely racked along the dank walls.

The final operation in rehabilitating telephone facilities consists in testing the cables and splicing them into the main control board of the city. One of the signalmen follows a cut sheet called the "brains," showing how the various pairs are to be spliced. Wires are scraped bare of insulation at the necessary points and the connecting wires are pigtailed to them, after which waxed cotton sleeves are adjusted to give these connections protection.

Substitutions in Signal Equipment Made by Army

United States Army Signal Corps has made substantial contributions in devising substitutes for strategic materials needed for signal equipment. This program has included basic research in developing new alloys, ceramics, and glass, and the work of testing and trying scores of substitute materials in practical application. A few which have been developed or sponsored by the United States Signal Corps are the following:

Low-grade mica for low-voltage capacitor applications.

Plastic materials for flashlights and signal lamps and special light projectors.

Plastic insulation for wires.

Magnesium instead of steel or aluminum or wood in radio chassis, antenna masts, and antenna mounts.

Plasticized ceramics developed as a substitute for mica in the manufacture of condensers.

Plasticized laminated paper and wood fiber in place of plywood.

Insulators made of glass instead of certain critically short ceramics.

Vibration absorbers, or shock mounts, made of substitutes for rubber.

Meteorological balloons made of substitutes for rubber.

Aviation Gas-Turbine Division Formed. Formation of an aviation gas-turbine division for the manufacture of military and, later, commercial gas-turbine aircraft engines, based on the jet engine, has been announced by L. E. Osborne, vice-president of Westinghouse Electric and Manufacturing Company. Manager of this division will be George H. Woodard whose headquarters will be at the South Philadelphia Works of the company. Reinout P. Kroon has been named manager of the engineering department.

INDUSTRY • • • • •

New Voice to Be Heard on Chilean Front

Station CB114, recently scheduled to go into operation, will be the first long-wave broadcast station to reach cities and towns throughout the 2,600-mile length of Chile, according to the Radio Corporation of America international division, whose Chilean company designed and built the station. CB114 was designed and built by Corporación de Radio de Chile, manufacturing subsidiary of RCA in Santiago. It is now owned and will be operated by the Corporación Chilena de Broadcasting, headed by Adriano Iz Reyes, station operator in Vina del Mar, Chile.

Completed on the plains outside the capital city of Santiago, this 50-kw station has been specially designed and situated to overcome the long-wave radio-transmission problems presented by Chile's rugged topography and long narrow geographical configuration. Because of these characteristics, the country heretofore has been dependent on short-wave broadcasting for national coverage.

The Corporación de Radio de Chile revealed that CB114's national coverage was achieved largely by means of a special type of directional antenna and an elaborate ground system which concentrate broadcast energy generally northward and southward. Although the station has a rated power of 50 kw, the special antenna and ground system provide an unmodulated carrier power of 135 to 140 kw to the North and South. The antenna is designed in a special pattern to fit the curve of the country. As its designation indicates, it will operate on a frequency of 1,140 kilocycles.

The plant incorporates a modern style of vertical-panel construction; an RCA 50-*E*-type transmitter, the same type as used by many United Nations broadcasting stations; complete automatic protection; air-cooled power tubes; a modern two-color streamlined enclosure; and a high-efficiency modulating system. Two transmitting masts, each 300 feet high and having a dead weight of 36 tons, are surrounded by an underground network of 22 miles of four-millimeter copper wire to assure high antenna efficiency.

Studios in downtown Santiago, equipped with high-fidelity RCA equipment, will pipe the programs to the transmitter either by telephone lines or by an ultrahigh-frequency link transmitter built in RCA's Santiago plant. Facilities are provided for handling four studios simultaneously, as well as for recording.

Nomograph Charts Issued for Radio Engineers

Nomograph charts never before available, providing radio engineers with an invaluable tool in the design of equipment for the ultrahigh-frequency and television ranges, have been issued by the Federal Telephone and Radio Corporation of Newark, N. J., associate of the International Telephone and Telegraph Corporation. The set now being offered, 25 in number, represents the beginning of a projected series of more than 100 graphic aids to the designer of radio, ultrahigh-frequency, and television equipment. Six of the charts now being offered are for use in the design of double- and triple-tuned band-pass circuits in the ultrahigh-frequency and television ranges, and provide a quick and easy means of answering the questions which arise in the design of such circuits. Two of the nomographs cover series and shunt-peaking methods of range extension in wide-band amplifiers; and other charts relate to impedance characteristics in various types of transmission lines, including single wires in troughs and in square outer conductors; balanced two-wire and concentric lines, air-spaced, and with solid dielectric; quarter-wave matching sections, and sending-end impedance in uniform lines.

Other charts treat transmission-line lengths, cutoff frequencies in circular wave guides, ultrahigh-frequency path lengths and optical line-of-sight distances. The remainder of the charts allow rapid calculation of deflection sensitivities of cathode-ray tubes, modulation percentages from oscillograms, reduction in gain caused by feedback, and dissipation of power in water-cooled devices.

Relay Stations Will Be Constructed. The American Telephone and Telegraph Company has filed application with the Federal Communications Commission for authority to construct seven relay stations between the terminals of the New York–Boston radio-relay project. FCC approval on the two terminals was granted last year. This route was selected for the experimental trial of microwave radio relay because of its nearness to the Bell Telephone Laboratories in New York and because of the continuing need for additional facilities between these two cities. The New York–Boston experiments are planned in three parts of the radio-frequency spectrum—near 2,000, 4,000, and 12,000 megacycles. Eight channel assignments, each 20 megacycles wide, are being requested in each of these parts of the spectrum.

Short-Wave Station in New Brunswick

Station CHTA, short-wave radio station in Canada, is beaming programs in several languages to Europe and soon will cover the world. This Government-owned station was built at Sackville, New Brunswick, in the salt marshland area. Its towers and antennas are designed to resist winds of 120 miles per hour. It is equipped with two transmitters each generating 50,000 watts, but a special beam antenna multiplies this 100 times, giving a total available power of 10,000,000 watts to the station. More than 26 miles of wire are used for the antennas and conducting lines between them and the transmitters. The antennas are strung up between towers varying in height from 170 feet to 380 feet. On the Great Circle Route, this particular location is one of the few places in Canada free of the north-magnetic-pole influences.

Power Project for Oregon Planned

The California Oregon Power Company, Yreka, Calif., has filed an application with the Federal Power Commission for a preliminary permit to construct a 40,000-kw hydroelectric project on the North Umpqua River in Douglas County, Oreg., 50 miles east of Roseburg. There have been few filings for permits for large power projects since the war began.

To be known as the Toketee Project, the proposed development would consist of a diversion dam about 500 feet downstream from the mouth of the Clearwater River; a tunnel in rock about 7,000 feet long across a bend in the river; a double line of steel penstocks; and a powerhouse with two 20,000-kw units.

It is the plan of the company to deliver the power to public and wholesale customers including Mountain States Power Company and Pacific Gas and Electric Company.

"Newsfront" Makes Debut. The initial issue of Westinghouse *Newsfront*, a new monthly publication by the Westinghouse Electric and Manufacturing Company, appeared in April. Featured in the first issue are the company's annual report, a story on a new application of the Precipitron air cleaner for the removal of "fly-ash," and a picture page illustrating recent Westinghouse developments. A four-page report, printed in two colors and illustrated contains short articles describing the latest achievements by the company in the fields of scientific research, engineering, and production.

New Synthetic Rubbers Put to Use. Fifty-three new synthetic rubbers were produced in the three synthetic rubber plants operated by United States Rubber Company during 1944, according to J. P. Coe, general manager of the company's Naugatuck chemical and synthetic-rubber divisions. Of these new rubbers eight types have been adopted for regular use in the manufacture of rubber insulation of electric wire and cable, porous-rubber storage-battery separators, asbestos sheet packing, and pressure-sensitive adhesives. Of the other 45 types, many are being evaluated. This work is being carried out under the supervision of Rubber Reserve Company as part of the Government's synthetic rubber program.

"Locomotive" Tests Radio Equipment. A highway "locomotive" is helping engineers in Baltimore test very high-frequency radio equipment for railroad radio communications. Cruising within a radius of ten miles from the radio and electronic laboratories of the radio division of Bendix Aviation Corporation, the "locomotive," a specially fitted truck, tests newly designed radio equipment under conditions approximating railroad operation. On daily runs radio technicians in the truck report continuously to other engineers at the plant laboratory by radio on changes in terrain being traveled by the truck. Records are kept at the plant of differences which occur in reception quality when the truck passes buildings, wires, or any types of electrical installations. Data are being compiled on the relative merits of amplitude-modulation and frequency-modulation equipment for mobile communications. On the daily runs the truck engineer switches from amplitude modulation to frequency modulation every ten seconds to provide comparative data.

"Heat in Harness" Course Is Given. An educational program in the heating industry has been initiated by the Minneapolis-Honeywell Regulator Company for interested persons associated with automatic heating. The courses are held in all sections of the United States where company branches are maintained and will cover four $2\frac{1}{2}$-hour meetings. More than 800 slides supplement the simple lectures which are conducted by company sales engineers who have been specially trained for the purpose. The primary purpose of the program is to teach the application of automatic controls and their installation and maintenance, in connection with the various types of heating systems using all kinds of fuel. In planning the course the company also had in mind the rehabilitation of men of the Armed Forces who by prior experience or by choice want to find jobs in some phase of the heating industry.

Demonstrate Uses of Wire Recording. Developments in wire recording and its uses for home entertainment, radio recording, office dictation, and the recording of telephone conversations were demonstrated recently by Lear, Inc., and by the Stromberg-Carlson Company. When wire recording is used for dictation in the business office, errors can be "erased" automatically while the correct words are inserted over the same portion of the wire. The improved models record and play back music with high fidelity which will assure their postwar application to the home radio receiver. Unwanted programs can be "erased" from the hair-thin wire to permit reuse. This eliminates costly upkeep and reveals a practical recording method where recording or dictating unwanted things need not result in loss to the user. Research work on wire recording has been conducted for many years.

Single-Crystal Transmitter Developed. A compact eight-channel mobile-service transmitter, which can be set for any frequency in the 100–156-megacycle band and uses but one crystal, has been developed by the radio division of the Bendix Aviation Corporation. It is usable in any type of mobile service and can be quickly converted from amplitude modulation to frequency modulation. A new three-dial eight-channel automatic shifter used in the unit has possibilities in multichannel applications. The number of dials could be varied on the basic design from one to ten, and as high as 16 channels ultimately could be incorporated into design. On any one of the eight channels, frequencies are determined accurately by dial calibration without the use of a crystal frequency indicator. The new transmitter was designed by R. B. Edwards of the division's transmitter engineering department.

OTHER SOCIETIES

Advances in "Movies" Will Be Presented. The 57th semiannual technical conference of the Society of Motion Picture Engineer will be held May 14–18, 1945, in Hollywood Calif. Advances in wartime military and naval use of motion pictures and in theate television, motion-picture sound recording and reproduction, and motion-picture photography and projection will be presented a nine technical sessions during the five-day conference. The use of film in television programs and the relationship of television and motion-picture practices are among the topics of scheduled papers.

ASA Plans Standards for Drafting Practices

The American Standards Association at the request of the War Production Board is developing a series of American War Standards for drawing- and drafting-room practice that will correlate the practices of the Army and Navy with those of industry. ASA has long had a regular committee on drawing- and drafting-room practice working under the joint technical leadership of the American Society of Mechanical Engineers and the Society for the Promotion of Engineering Education. Standards developed by this committee have laid down the simple basic elements of the subject. This new work proposes to carry the subject further into the realm of modern industrial production.

Work on these new War Standards, which has already been started, is being financed by the War Production Board through an already existing Government contract under which the ASA since July 1942 has completed 88 Standards of direct concern to the war effort and has under development some 68 more.

The War Department has outlined the scope of the work to include civil, mechanical, electrical, aeronautical, and marine engineering, and such subjects will be covered as the following: abbreviations; methods of indicating and specifying threads; methods of lettering; drawing forms and sizes; graphical, diagrammatic and schematic symbols; methods of indicating and specifying materials; methods of indicating and specifying finishes; methods of dimensioning and indicating tolerances; and methods of numbering drawings.

New Radio Section Formed. A new section of the Institute of Radio Engineers, the Cedar Rapids section with 118 members, has been formed. At the April 11 meeting R. L. Campbell and R. E. Colander presented papers. Mr. Campbell discussed quartz crystals from a structural point of view and Mr. Campbell's paper dealt with circuit functions of piezoelectric crystals. At the March 19 meeting at the Hotel Roosevelt in Cedar Rapids 96 persons were present and heard the guest speaker W. L. Everitt (A '25, F '36) national president of the Institute of Radio Engineers, talk on wartime development of electronics. Officers were elected and installed for the year 1945.

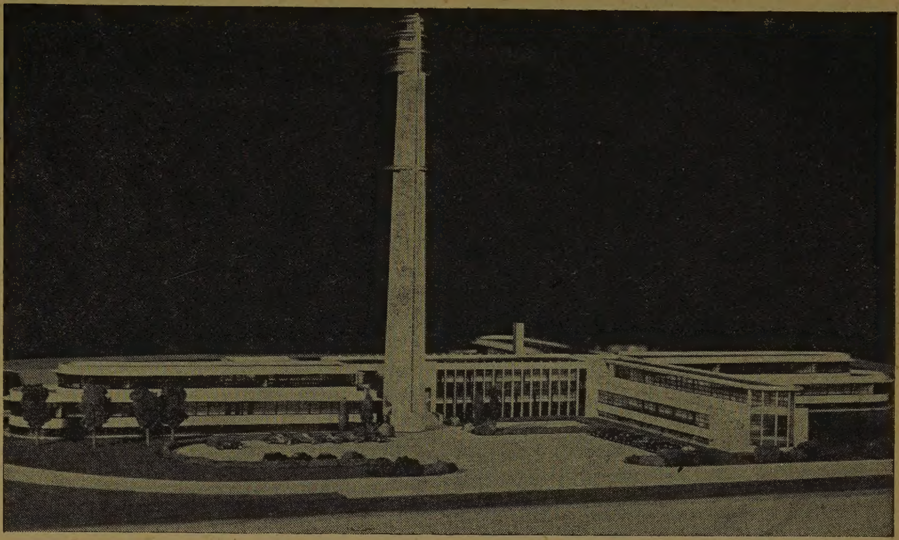
RESEARCH

Scientists Will Co-ordinate Research Work

Through the formation of a $2,000,000 corporation uniting their efforts, electronic scientists of International Telephone and Telegraph Corporation functioning in the United States and numerous other countries will be grouped in a world-wide organization, with headquarters in the United States. The scientific corporation, formed in Delaware as International Telecommunication Laboratories, Inc., was created to make possible ultimately an exchange of inventions and closer co-ordination of the corporation's electronic research work, including advancements in radio, television, and other branches of the communications arts and the aids to aerial navigation which they will afford in the postwar era.

E. M. Deloraine, general director of Federal Telephone and Radio Laboratories, New York, is president of the organization. The corporation is owned jointly by International Telephone and Telegraph and a subsidiary, International Standard Electric Corporation. Among the other officers elected were Harold H. Buttner and Douglas B. Baker (M '27) vice-presidents; Paul F. Swantee, comptroller; O. C. Buchanan, treasurer; and C. Douglas Webb, secretary.

Proposed Headquarters for Electronic Research



The designer's conception of new laboratories, the first unit of which is now under construction at Nutley, N. J., for postwar activities of International Telecommunication Laboratories, Inc.

EDUCATION

Course Offered in Iowa City. A three-week management course is being offered again this year by the State University of Iowa in Iowa City from June 11 to June 29. Designed primarily for people in industry who want comprehensive training in production planning, plant layout, motion-and-time study, and wage incentives, the program includes fundamental training with practical applications. The course will benefit especially those executives who are responsible for reducing manufacturing costs and increasing production. Attention will be given to procedures to be followed in conducting factory training programs in this field. Conducted as it has been for the past seven years, the course will be held under the direction of Ralph M. Barnes, professor of industrial engineering at the university. Tuition and laboratory fee for the three-week course is $150. Advance registration is required, for enrollment will be limited, and applications will be accepted in the order of their receipt.

Appropriations for Pursuit of Science. Because the Rockefeller Foundation believes that the United States has wasted its scientific patrimony for war needs, appropriations have been made from limited funds to train young men under the auspices of the National Research Council and the Social Science Research Council. In a 63-page review of the foundation's work during 1944 Raymond B. Fosdick, president, contrasted the methods of this country with Russia and England where the future is protected by guarding the flow of new scientific personnel. He stated that in Russia students of ability in science are not permitted in the Armed Forces whereas in the United States scientific professors and students alike largely have left the universities. The report stated that the foundation financed nine projects in the natural sciences in England last year, seven in Sweden, and two in Switzerland. Doctor Fosdick praised the scientists who made their laboratories available to refugee scientists.

HONORS

Scientific High Command Donates Award to Academy

The six American scientists foremost in mobilizing the country's scientific resources for war recently were honored with the eighth annual American Design Award, and at their request the award was presented to the National Academy of Sciences as the body that represented all scientific endeavor in America. Presentation of the $25,000 check and accompanying certificate recognizing the organizers of the means for creating new weapons, new airplanes, and vehicles; new medicines; and new materials was made by Walter Hoving, president of Lord and Taylor, New York, N. Y., donors of the award. Frank B. Jewett (F '12) president of the academy, accepted the award on its behalf.

The scientists so honored were: Vannevar Bush (F '24) director, Office of Scientific Research and Development; James Bryant Conant, chairman, National Defense Research Committee; Karl T. Compton (F '31) chief of the field service for the NDRC; A. Newton Reichards, chairman, Committee for Medical Research; Jerome C. Hunsaker, chairman, National Advisory Committee for Aeronautics; and Ross G. Harriman, chairman, National Research Council.

Speakers at the ceremonies included Doctor Compton, Doctor Jewett, and Mr. Hoving.

Doctor Compton warned that, "if we are not to become an easy and inviting prey to the next well-prepared aggressor, we must be alert to be ourselves prepared to meet what may come." "In order," he said, "that the United States may be safe it must be just and co-operative in its international dealings, but it must also be strong internally." Stressing scientific preparedness as one aspect of this strength, he stated that no nation would attack us again, unless it were convinced of a speedy victory by superior technical methods. "The Nazis, Fascists, and Japs were encouraged, not deterred, by the pledges of our youth never to bear arms, or by our refusal to strengthen the defenses of Guam, or to mount modern guns on Corregidor," he declared.

Doctor Jewett pointed out that wartime co-operation among scientists augured well not only for a more decent postwar world but for a greater national security. The award money, he added, would be spent "in the encouragement of research in those things which are deemed most likely to enhance the security of our country."

Alexanderson Receives Swedish Gold Medal

Doctor E. F. W. Alexanderson (F '20) consulting engineer, the General Electric Company, Schenectady, N. Y., has been awarded the Cedergren gold medal of the Royal Institute of Technology, Stockholm, Sweden. The medal, which was instituted by the will of the late Henrik Tore Cedergren, telephone pioneer of Sweden, has been conferred upon Doctor Alexanderson, "not only as a tribute to a great man of science, but also as a symbol of international friendship and co-operation."

In his presentation of Doctor Alexanderson for the award, Harry Stockman, Harvard University, lauded his personal character as well as his attainments in the field of electrical engineering. "Doctor Alexanderson's outstanding characteristics are his lack of fear of difficulties, his accomplishment of the seemingly impossible, his straightforward manners, and his honest approach to his work. These traits were much in evidence in his design of an alternator for a frequency of 100,000 cycles per second, an alternator which everyone thought could not be designed; in his execution of a specially ventilated 1,500-volt d-c motor with which he won an international competition in Melbourne, Australia; and in his work in facsimile transmission and television. In recognition of his ability, in 1940 Doctor Alexanderson's name was listed on the New York World's Fair 'Wall of Fame' honoring foreign-born citizens who have made notable contributions to American democracy."

The Cedergren medal was presented to Doctor Alexanderson by the Swedish Consul General, Martin Kastengren, at a dinner of the American Society of Swedish Engineers held on February 9, 1945, at the Restaurant Stockholm, in New York, N. Y.

A. H. Compton Receives 1945 Washington Award

The Washington Award for 1945 has been conferred upon Arthur Holly Compton, dean, division of physical science, and chairman, department of physics, University of Chicago.

The Washington Award was established in 1916 by Past President Alvord of the Western Society of Engineers and is presented annually by the Washington Award Commission, composed of nine representatives of the Western Society of Engineers and two each from the American Society Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, and the AIEE, to the engineer who has done some outstanding work or whose services in general have been directed toward promoting the public good.

POSTWAR

Veterans From Colleges to Organize. The first veterans' organization on a national scale to grow out of World War II has been announced by the organizing chapter at the Polytechnic Institute of Brooklyn. The new association, known as the Gamma Iota Alpha ("GI Association") is for honorably discharged members of any branch of the Armed Forces who are attending college or who have attended college. Servicewomen also are entitled to join the association. The founding chapter at Polytechnic Institute is acting as national headquarters for the organization until such time when a meeting can be held and a permanent constitution drawn up. Announcement of this proposed intercollegiate veterans' organization has been forwarded to 800 colleges and universities in the United States. Information for installing chapters already has been forwarded to groups at Illinois Institute of Technology, Duke University, Ohio State University, Lehigh University, Louisiana State University, University of North Dakota, University of Wyoming, Boston University, Pratt Institute, Brooklyn College, and Queens College. Beta and Gamma Chapters are active in St. John's University and Long Island University.

JOINT ACTIVITIES

New Canadian Council Formed. A new national body has been formed in Canada with headquarters in Ottawa called the Canadian Council of Professional Engineers and Scientists. The main purpose of the council is the co-ordination of all aims and efforts of Canadian engineers and scientific workers on matters affecting the public interest in general and the professional interest in particular. Matters such as collective bargaining, ratings in the Armed Forces, national selective service, postwar employment, national-research policies will be dealt with by the council, and through its formation Canadian Government departments now will have one direct channel of approach for all questions of legislation which concern professional engineers and scientists. With the establishment of a liaison officer in Ottawa having close connections with the Dominion Government, interests of engineers may be surveyed more adequately before legislation is enacted rather than after it becomes a legal statute. At present the body functions as a council on which the senior officer of each supporting society acts as a voting member. W. J. Gilson vice-president, AIEE District 10, Eastern Power Devices Ltd., Toronto, Ontario, Canada, will supply information to those interested.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication herein no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Calculating Antenna Radiation Patterns

To the Editor:

I wish to clear up a misunderstanding in the discussion of "Calculating Antenna Radiation Patterns" by R. W. Cronshey (*EE, Sept. '44, pp. 331–4*). In Mr. Cronshey's reply to my letter in the March issue of *Electrical Engineering*, he is quite right in stating that, if the square-root signs were inserted in all places mentioned, the calculations would still be correct. The results given in the original article would then be true for $\sqrt{(P_D/P_A)}={}^1/_2$ or $P_D/P_A={}^1/_4$ (see Table I, column 4).

My calculations were designed to give the results for the power ratio $P_D/P_A={}^1/_2$, as implied by the original article. However, I inadvertently took $\sqrt{(P_D/P_A)}={}^1/_4$ instead of $1/\sqrt{2}$, thus leading to erroneous and confusing results. For the power ratio $P_D/P_A={}^1/_2$, the correct figures are: $\sqrt{(P_N/P_A)}$ sin $=0.62$; $\sqrt{(P_N/P_A)}$ cos $=0.34$; $Y=-1.28$; $X=0.79$; $E_P/E_A=1.50$.

With this correction made, I am sure that we are in full agreement as to the results.

HERBERT L. KRAUSS (A '42)

(Assistant professor of electrical engineering, Yale University, New Haven, Conn.)

Applications of Thevenin's Theorem

To the Editor:

Walther Richter's article, "Applications of Thevenin's Theorem," (*EE, Mar '45, pp. 103–5*) will do much to lighten the work of network calculation for those who do not already make use of the theorem, particularly as the well-chosen examples not only extend into noncommunication fields but emphasize the use of the theorem in network synthesis rather than analysis alone, with which latter many of us are prone to associate it.

It follows that Thevenin's theorem has a corollary, Norton's theorem, which, together with its proof, I have put in the same phraseology as that of Mr. Richter's article. While the corollary appears to be no more useful, and in many cases less so than the theorem itself, it may be of some interest. The corollary and its proof follow:

Corollary. The voltage across any single branch of a network consisting of any number of impedances and voltage sources can be found in the following manner: short-circuit the branch under consideration, and determine the short-circuit current; then consider all voltage sources as short-circuited or—if they have internal impedance—replaced by an impedance equal to the internal impedance of them, and calculate the impedance of the network when measured across the branch in question (with the short circuit removed). The voltage that will appear across the branch under consideration will be the short-circuit current multiplied by this impedance.

Proof of Corollary. Assume that in a network consisting of linear impedances, $z_1, z_2, \ldots z_n$, and voltage sources, $E_1, E_2, \ldots E_m$, it is desired to determine the voltage drop across z_k. Upon reducing the impedance of this branch to zero (by means of a zero-impedance jumper) a short-circuit current I_{ks} will result and the voltage e_k, of course, will be zero. Now suppose that in series with the zero-impedance jumper is connected a current source of such sign and magnitude as to reduce the original branch current i_k (and consequently e_k) to zero. This obviously will not change anything from the short-circuit condition of the branch z_k, as far as the rest of the network is concerned. There is now a network with no short-circuited branches but with a new current source equal to I_{ks} introduced into the network. The voltage distribution in the network now is determined by the original m voltage sources plus the new current I_{ks}. But under the new condition the branch voltage across z_k is zero, and, according to the superposition principle, the introduction of I_{ks}, with all the voltage sources short-circuited, must be such as to cancel exactly the original current in (and voltage across) the branch z_k. The voltage originally across z_k therefore must be equal to a voltage that would exist, if all original voltage sources were short-circuited, but a current source equal to but opposite in polarity to I_{ks} had been introduced across the branch z_k. This proves the corollary to Thevenin's theorem.

Both the article and the foregoing remarks might have been a little more rigorous with provision in the network for current sources and their internal shunt impedances, but these cases (such as pentode amplifier circuits) are easily included.

SIDNEY B. WILLIAMS (A '37)

(Assistant project engineer, propeller division, Curtiss-Wright Corporation, Caldwell, N. J.

NEW BOOKS • • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question

Metallography of Magnesium and Its Alloys. A translation from the German by the technical staffs of F. A. Hughes and Company Ltd. and Magnesium Elektron Ltd. of "Metallographie des Magnesiums und seiner technischen Legierungen." By W. Bulian and E. Fahrenhorst. F. A. Hughes and Company, Ltd. London, England, 1944. 117 pages, illustrated, $9^1/_2$ by 6 inches, cloth, 15*s*. (ESL.)

This, the first book devoted solely to the metallography of magnesium and its alloys, appeared in Germany in 1942. The translation is by the staffs of British producers of the metal. The book opens with a short description of polishing and etching technique, which is followed by a description of the alloy constituents and impurities that are discernible in micrographs. The remainder of the book discusses 225 micrographs that are presented and the information that they reveal as to the nature of the alloy, its pretreatment, and its faults. To the references in the original edition, the translators have added a list of non-German references.

MacRae's Blue Book and Hendrick's Commercial Register, 52d annual edition 1944–45. MacRae's Blue Book Company, Chicago, Ill., and New York, N. Y., 1945. 3,736 pages, illustrated, 11 by 8 inches, cloth, $15. (ESL.)

The major part of this standard annual buyers' guide is a comprehensive alphabetical list of products with the manufacturers arranged alphabetically under each product. In some of the larger classifications there is both a geographical and alphabetical arrangement. Preceding this section is a complete alphabetical file of manufacturers giving full addresses, capital ratings, and local distributors. A 300-page list of trade names is included at the back of the volume.

Annual Report on the Progress of Rubber Technology, volume 7, 1943. Edited by T. J. Drakeley, published by W. Heffer and Sons, Ltd., Cambridge, England, for the Institution of the Rubber Industry, London, England, 1944. 129 pages, $9^1/_2$ by 7 inches, paper, 12*s*.6*d*. (4*s*.6*d*. to members). (ESL.)

This annual contains excellent reviews of developments in various fields: production, chemistry and physics, synthetic rubber, compounding, fibers and textiles, vulcanized rubber, tires, belting, hose and tubing, cables and electrical insulation, footwear, mechanical goods, flooring, surgical goods, solvents, sponge rubber, hard rubber, works processes, and machinery. Each report includes a bibliography. Name and subject indexes are provided.

Theory and Applications of Electron Tubes. By H. J. Reich. Second edition. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1944. 716 pages, illustrated, 9 by $5^3/_4$ inches, cloth, $5. (ESL.)

This book is intended to give, in one volume, a sufficiently thorough grounding in the fundamentals of electron tubes and associated currents to enable the student to apply these tubes to the solution of new problems. The basic principles are presented, and special attention is given to their application to industrial electronics, power control, electrical measurements, and other fields of use. The new edition has been brought up to date.

Metallography and Heat-Treatment of Steel. Volume 3, Ferrous Metallurgy (Mineral Industries Series.) By E. J. Teichert. Second edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1944. 577 pages, illustrated, $8^1/_2$ by $5^1/_4$ inches, cloth, $5. (ESL.)

The text on ferrous metallurgy, of which this is the final volume, is intended especially for those employed in the steel industry who wish to acquire a working knowledge of fundamental principles. In this volume the physical metallurgy of the iron and steel alloys, metallography, and heat treatment are considered. The work is well adapted for private study.

Readjustment of Man Power in Industry During the Transition From War to Peace. (Research Report Series 71.) By H. Baker. Princeton University, Princeton, N. J., 1944. 112 pages, tables, $9^1/_4$ by 6 inches, paper, $1.25. (ESL.)

The material presented constitutes an analysis of the policies and programs presently under consideration by industry for absorbing the returning man power after the war. The results of a large number of discussions with industrial, union, and government executives are grouped under three headings: organization and extent of company planning; transitional adjustments in the present labor force; employment and reemployment of veterans.

Symposium on Plastics. American Society for Testing Materials, Philadelphia, Pa., 1944. 200 pages, illustrated, 9 by 6 inches, paper, $1.75; cloth, $2. (ESL.)

Of the 16 papers by authorities in the field presented in this publication, the first eight deal with such topics as the heat resistance of laminated plastics, diffusion of water through plastics, and the behavior of plastics under certain conditions and test methods. The rest of the papers are grouped together as a summary of properties, uses, and salient features of the following families of plastics: phenolics, polystyrenes, urea and melamine, allyl, vinyl, cellulose, methacrylate, and nylon plastics.

High-Speed Combustion Engines. By P. M. Heldt (12th edition of "The Gasoline Motor") published by the author, Nyack, N. Y., 1944. 776 pages, illustrated $8^1/_2$ by $5^1/_4$ inches, cloth, $7.50. (ESL.)

This standard work, now in its 12th edition, provides a comprehensive reference book for engineers as well as a textbook for students. The separate working parts of the high-speed combustion engine are covered in detail, including chapters on the carburetor and ignition equipment not previously included. Theory, design principles, production practice, and operation all are given consideration, and two chapters are devoted to engine tests and the thermodynamic laws.

Vibration Analysis. By N. O. Myklestad. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1944. 303 pages, illustrated, $8^1/_2$ by $5^1/_4$ inches, cloth, $3.50. (ESL.)

The first five chapters are written from the textbook point of view to provide an understanding of the various phases of the phenomenon of vibration. Important topics covered are undamped and damped vibrations of systems of one degree of freedom and vibrations of systems with more than one degree of freedom. The last chapter deals with applications to important practical problems, chiefly in the aeronautical field.

The Industrial Supervisor. By J. M. Amis and T. C. Sutton. Ronald Press Company, New York, N. Y., 1944. 243 pages, illustrated, $8^1/_4$ by $5^1/_4$ inches, cloth, $3. (ESL.)

The opening chapters discuss general supervisory responsibilities and the general qualifications of a supervisor. Succeeding chapters deal with the many specific responsibilities of the supervisor from a practical viewpoint, provide necessary technical information, and show how particular qualifications may be gained or improved. The book is intended for home study, industrial training departments, or conference discussions by small groups.

Principles of Physics, volume 1, Mechanics, Heat, and Sound. By F. W. Sears. Addison-Wesley Press, Cambridge 42, Mass., 1944. 526 pages, illustrated, $9^1/_4$ by 6 inches, cloth, $5. (ESL.)

This text is based on the first course in physics given at the Massachusetts Institute of Technology. It covers the subjects: mechanics, heat, and sound, which form the first year of the two-year course, and is given to students who are concurrently given a course in analytical geometry and calculus. The emphasis throughout is on physical principles, and the calculus is used freely. Numerous problems are provided.

Engineering Mathematics. By H. Sohon. D. Van Nostrand Company, Inc., New York, N. Y., 1944. 278 pages, illustrated, $9^{1}/_{4}$ by 6 inches, cloth, $3.50. (ESL.)

This book is intended for engineering students who have completed the study of the elementary calculus and for graduate engineers seeking to bolster their present knowledge of mathematics. Determinants and matrix theory, Fourier series, differential equations, vector algebra, and vector calculus are important subjects dealt with in the text. The theory and solution of algebraic equations in general are effectively covered.

Milling Machine Operations. By L. E. King. The Macmillan Company, New York, N. Y., 1944. 123 pages, illustrated, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, paper, $1.75. (ESL.)

This guide for apprentices and students in shop courses is intended to teach the performance of various milling-machine operations.

Engineering Contracts and Specifications. By R. W. Abbett. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, Ltd., London, England, 1945. 188 pages, illustrated, $8^{3}/_{4}$ by $5^{3}/_{4}$ inches, cloth, $2.25. (ESL.)

Upon the basis of experience both as a teacher and a contractor, the author has attempted to present in compact form some of the legal and business aspects of the engineering profession. The legal considerations in construction work are summarized, the types of contracts are described, and the essentials of each type are discussed. Examples of each type are shown. Bidding procedure is described and a chapter is devoted to specification writing.

Theory of X-Ray Diffraction in Crystals. By W. H. Zachariasen. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, London, England, 1945. 255 pages, illustrated, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $4. (ESL.)

This book aims to give a logical presentation of both the theory of crystal symmetry and the theory of X-ray diffraction in crystals.

Intermediate Aerodynamics. By R. W. Truitt. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1944. 227 pages, illustrated, $9^{1}/_{4}$ by 6 inches, cloth, $3.75. (ESL.)

The important elements necessary for the accurate application of aerodynamics are presented with sufficient descriptive material to emphasize their practical use. Thorough mathematical explanations are given for problems relating to the airfoil, drag, stability, load factors, propellers, slots, and flaps. A glossary of aeronautical terms is appended.

Plastics in the World of Tomorrow. By B. W. Leyson. E. P. Dutton and Company, New York, N. Y., 1944. 184 pages, illustrated, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, cloth, $2.50. (ESL.)

A general survey of the subject intended for nontechnical readers is provided in this book. The various plastics are described, their uses enumerated, and future possibilities discussed.

Enamel Bibliography and Abstracts, 1928 to 1939. Compiled by E. H. McClelland; edited and published by the American Ceramic Society, Columbus, Ohio, 1944. 352 pages, tables 11 by $7^{3}/_{4}$ inches, cloth, $5. (ESL.)

This compilation provides full references to the literature published during the period, 1928–39, with excellent abstracts. The arrangement is by authors, with an extensive detailed subject index. The bibliography is a model for such works.

Chambers's Technical Dictionary. Edited by C. F. Tweney and L. E. C. Hughes. Revised edition with supplements. The Macmillan Company, New York, N. Y., 1944. 975 pages, illustrated, $8^{1}/_{4}$ by $5^{1}/_{4}$ inches, cloth, $6. (ESL.)

This dictionary defines terms used in pure and applied science, in engineering and construction, in manufacturing, and in the skilled trades. The new edition has been revised and a supplementary list of nearly 1,000 definitions added.

Airport Engineering. By H. O. Sharp, G. R. Shaw, and J. A. Dunlop. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1944. 150 pages, illustrated, $11^{1}/_{4}$ by $8^{1}/_{2}$ inches, cloth, $5. (ESL.)

This undergraduate textbook presents concisely the problems that confront the airport builder. After a brief discussion of airport size and site, planning and preliminary surveys are considered. Problems of grading, drainage, soil stabilization, and paving then are treated. Finally, lighting, buildings, and construction and maintenance equipment are presented.

Comfortization of Aircraft. By A. A. Arnhym. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1944. 347 pages, illustrated, $9^{1}/_{4}$ by 6 inches, cloth, $7.50. (ESL.)

Looking to the future, designers and others associated with the airplane industry and air transport are concerned with passenger comfort and conveyance. The author has assembled technical data, calculations, information, and illustrations useful in eliminating the discomforts of flying. He outlines the various important phases, and gives a detailed analysis of air supply, heat supply, soundproofing, seating, berthing, catering, and the like. Procedures and methods are included for incorporating, specifying, selecting, and servicing comfort equipment.

General Meteorology (published formerly under the title, "Synoptic and Aeronautical Meteorology"). By H. R. Byers. McGraw-Hill Book Company, New York, N. Y., and London, England, 1944. 645 pages, illustrated, 9 by $5^{1}/_{2}$ inches, cloth, $5. (ESL.)

This book is designed as a general tex
embodying the fundamentals as well as th
modern development in synoptic meteoro
ogy, including recent advances in the fiel
such as: isentropic analysis and new fore
casting uses of upper-air pressure chart
The last five chapters of the book cover ma
terial of particular importance in aeronautic
An appendix contains practical aids for th
student and meteorologist.

Helicopter Design Theory. By A. A
Nikolsky. Princeton University Pres
Princeton, N. J., 1944. 228 pages, illustrate
9 by 6 inches, paper, $3. (ESL.)

This volume presents at series of lecture
given at Princeton University in the spring
1944 to a group of engineers representin
the Army and Navy air services and variou
aircraft manufacturers. The treatment
theoretical and mathematical and, of neces
sity, tentative, as theory in this field is sti
in an unstable state.

**Heating Ventilating Air Conditionin
Guide.** 23d edition. American Societ
of Heating and Ventilating Engineers, Ne
York, N. Y., 1945. 1,216 pages. 6 by
inches, $5.

This edition contains 48 chapters of tech
nical data and information grouped unde
the general subdivisions, Principles; Heatin
and Cooling Load Calculations; Combustio
and Consumption of Fuels; Steam and Ho
Water Heating; Air Heating, Cooling an
Conditioning; Automatic Controls, Instru
ments and Motors; Special Applications, an
Miscellaneous. Many chapters have bee
rewritten or revised, and new material ha
been added to the chapters on Terminolog
as well as Abbreviations, Symbols, Standards
and conversion equations and constant
listed have been corrected to agree wit
latest accepted values of the National Burea
of Standards. This edition contains 80
pages of technical data; 344 pages of equip
ment data and the Roll of Membership o
the Society. A 15-page index, a single-pag
quick-reference table of contents, and a brie
summary of chapter contents under eac
chapter heading provide easy reference t
subjects treated in this book.

PAMPHLETS • • •

**The following recently issued pamphlets may b
of interest to readers of "Electrical Engineering.
All inquiries should be addressed to the issuer**

Patent Digest Service (Resins, Rubber
Plastics), volume 1, issue 1. Interscienc
Publishers, Inc., New York 3, N. Y.

**War Production and V-E Day, Second Re
port.** By the Director of War Mobilizatio
and Reconversion, Washington, D. C., 4
pages.

Steam Power Plant Planning Guide (10,00
to 60,000 kw). Westinghouse Electric an
Manufacturing Company, Lester Branc
Post Office, Philadelphia 13, Pa.

The Story of the Diesel. The Diesel Engin
Manufacturers Association, Chicago 2, Ill
32 pages.

Panoramic Reception (From One Ham t
Another). Panoramic Radio Corporatio
New York, N. Y. 31 pages.